



Future Directions of Municipal Solid Waste Management in Africa

Romeela Mohee and Thokozani Simelane (eds)

VISIT...

LANZAROTE
Caliente.COM

Future Directions of Municipal Solid Waste Management in Africa

Romeela Mohee and
Thokozani Simelane (eds)

Future Directions of Municipal Solid Waste Management in Africa

First Published in 2015 by the
Africa Institute of South Africa
PO Box 630
Pretoria 0001
South Africa

ISBN: 978-0-7983-0423-8

© Copyright Africa Institute of South Africa 2015

No part of this publication may be reproduced, stored in a retrieval system, or transmitted by any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without prior permission from the copyright owner.

To copy any part of this publication, you may contact DALRO for information and copyright clearance.

Any unauthorised copying could lead to civil liability and/or criminal sanctions.



Telephone: 086 12 DALRO (from within South Africa); +27 (0)11 712-8000
Telefax: +27 (0)11 403-9094
Postal Address: P O Box 31627, Braamfontein, 2017, South Africa
www.dalro.co.za.

Opinions expressed and conclusions arrived at in this book are those of the authors and should not be attributed to the Africa Institute of South Africa.

Project Manager: Mmakwena Chipu
Editing: Linda Botha Language Services
Proofreading: Write Skills
Design and Layout: Pamset
Cover Design: Berekile Pila
Printing: Seriti Printers

The Africa Institute of South Africa is a think tank and research organisation, focusing on political, socio-economic, international and development issues in contemporary Africa. The Institute conducts research, publishes books, monographs, occasional papers, policy briefs and a quarterly journal – Africa Insight. The Institute holds regular seminars on issues of topical interest. It is also home to one of the best library and documentation centres world-wide, with materials on every African country.

For more information, contact the Africa Institute of South Africa at PO Box 41, Pretoria 0001, South Africa; Email publish@hsr.ac.za; or visit our website at <http://www.ai.org.za>

Table of Contents

Acknowledgements	v
Foreword	vi
About the Editors	viii
About the Contributors	ix
Abbreviations and Acronyms	xiv
CHAPTER 1	
Introduction	
<i>Thokozani Simelane and Romeela Mohee</i>	1
CHAPTER 2	
A Comparative Analysis of Solid Waste Management in Developed and Developing Countries	
<i>Romeela Mohee and Muhammad Ali Zumar Bundhoo</i>	6
CHAPTER 3	
Solid Waste Collection and Transportation	
<i>Oomesh Gukhool</i>	36
CHAPTER 4	
Treatment of Solid Waste: Principles, Key Technologies and Case Studies from Africa	
<i>Ackmez Mudhoo, Geeta Devi Somaroo and Romeela Mohee</i>	54
CHAPTER 5	
Moving up the Hierarchy: Involving the Informal Sector to Increase Recycling Rates – A Case Study of Nigerian Cities	
<i>Thaddeus Chidi Nzeadibe</i>	70
CHAPTER 6	
Effective Integration of Scavengers in Solid Waste Recycling and Material Recovery	
<i>George Teke Forbid and Günter Busch</i>	88
CHAPTER 7	
Solid Waste Management in Uganda: Challenges and Options	
<i>James Okut-Okumu</i>	107

CHAPTER 8

**The Role of Policy and Institutional Reforms in Enhancing
Technical Efficiency of Urban Authorities: Reference to
Solid Waste Management in Kampala City, Uganda**

Judith Tumusiime Tukahirwa and Najib Bateganya Lukooya

136

CHAPTER 9

**Technology must Seek Tradition: Re-engineering Urban Governance
for Sustainable Municipal Solid Waste Management**

Martin Oteng-Ababio

155

CHAPTER 10

**Leading the Way: Directions of Municipal Solid
Waste Management in South Africa**

Luke Chimuka and Jason Ogola

176

CHAPTER 11

**Innovations in Municipal Solid Waste Management:
Experiences from eThekweni Municipality, South Africa**

Trynos Gumbo and Thokozani Simelane

202

CHAPTER 12

**Localised Approach to Solid Wastes Management: System Dynamics,
Life-cycle Assessment, Institutional and Legislative Frameworks**

Geeta Devi Somaroo and Oomesh Gukhool

218

CHAPTER 13

Conclusion: The Holistic Picture and the Way Forward

Ackmez Mudhoo, Romeela Mohee and Thokozani Simelane

239

Acknowledgements

This volume is the result of a successful partnership between the Africa Institute of South Africa (AISA) and the International Council of Science Union: Regional Office for Africa (ICSU ROA). Their contribution to the successful publication of the book, which outlines future directions of municipal solid waste management in Africa, is greatly acknowledged. The Editors would like to extend their heartfelt gratitude to researchers who agreed to make contributions to the book. Many thanks go to Mr Charl van der Merwe, for the wonderful task he performed as project coordinator. AISA's Research and Publications Divisions, oversaw the publication of the book.

Foreword

Solid waste is a perpetual problem for most countries in Africa. This is compounded by the fact that environmentally-sustainable waste-management systems are constrained by a number of limitations. Most municipalities seem to have inadequate resources to handle municipal solid waste. They concentrate their efforts on collection and land disposal of municipal solid waste. However, technologically advanced methods have been developed across the world, with developed countries leading the way as to how municipal solid waste should be integrated into sustainable development strategies of municipalities. The inability of African municipalities to find alternative uses for municipal solid waste means that a clean and healthy environment in Africa is a privilege reserved for the few. This is despite the African Charter on Human and Peoples' Rights stressing that all people have the right to a generally satisfactory environment, favourable for their development. This work, by selected African environmental researchers, seeks to chart directions for municipal solid waste management in Africa.

Municipal solid waste management constitutes one of the crucial services that must be provided by the municipalities to citizens. It is therefore important that municipalities devise strategies for attaining sustainable solutions to municipal solid waste management. This requires innovation; and this volume provides models of innovative waste management in Africa. Specific references have been made to the municipality of eThekweni in South Africa, selected Nigerian cities and Kampala in Uganda. The eThekweni Municipality has been presented as a successful case study for innovative waste management that warrants consideration by other municipalities in the continent. The volume also outlines legislative frameworks and attempts, by various African countries, to provide innovative and alternative uses of municipal solid waste. The key consideration is that legislation and municipal solid waste management strategies need to be seen as a resource that is directly linked to environmental sustainability and development. What Africa is experiencing at the moment is that the social and economic transformations taking place in most countries have directly influenced the amount of waste produced. This phenomenon has imposed pressure on authorities to upscale and provide better solid waste management services and solutions, and requires a high degree of innovation. The implementation of successful waste management strategies depends first and foremost on political stability and political willingness. A stable government ensures that policies adopted remain in place longer, and this allows sufficient time for a

proper waste management strategy to evolve and improve over time. In Africa this seems not to be possible, due to widespread political instability in some countries. This implies that carving out future directions of municipal solid waste management is an ever-evolving endeavour.

Dr Edith Madela-Mntla

Director

ICSU ROA

About the Editors

Romeela Mohee

Romeela Mohee is the Vice-Chancellor of the University of Mauritius. She has held the position of National Research Chair in Solid Waste Management for the period 2012 to 2013. A professor in the field of Chemical and Environmental Engineering, her research areas are mainly focused on waste containment, solid waste management by composting and anaerobic digestion, as well as the beneficial re-use of waste materials. She earned her Ph.D. from the University of Mauritius, and was a Fulbright Scholar in 1998. She has more than 24 years' experience in academic teaching and research. She has over 75 international journal and conference papers to her credit, and has supervised more than 15 successful Masters and Ph.D. students in the field of Waste Engineering and Management.

Thokozani Simelane

Thokozani Simelane is a Chief Research Specialist and Leader of a Science and Technology Research Programme at the Africa Institute of South Africa within the Human Research Sciences Council, Pretoria, South Africa. He holds a Ph.D. in Biodiversity Management from the Nelson Mandela Metropolitan University, and is finalising his second Doctorate in Industrial Engineering, specialising in systems analysis. He is a member of South Africa's standing advisory committee on Intellectual Property Rights, where he also serves as a member of the Patents sub-Committee. He is also a member of South Africa's competitiveness Research Focus Group. He serves as a resource person on energy to the South African Parliamentary Portfolio Committee on Energy. His research interests include complex system analysis; biodiversity and environmental management; science and technology; intellectual property development and management; renewable energy and standardisation. He has published extensively in accredited Journals.

About the Contributors

Ackmez Mudhoo

Ackmez Mudhoo is currently a Lecturer in the Department of Chemical and Environmental Engineering at the University of Mauritius, and is a Ph.D. candidate in Chemical Engineering. He holds a B.Eng. (Hons) degree in Chemical and Environmental Engineering and an M.Phil. degree in Chemical Engineering from the University of Mauritius. His main research interests are in the bioremediation of organic wastes and waste waters, adsorption and the related mathematical modelling. He serves as a peer-reviewer for the Waste Management Journal of Hazardous Materials, Environmental Engineering Science, Chemical Engineering Journal, Chemical Engineering Communications and Water Research. He is an Associate Editor of the Editorial Board of Environmental Chemistry Letters (Springer).

Geeta Devi Somaroo

Geeta Devi Somaroo is a Lecturer in the Department of Chemical and Environmental Engineering in the Faculty of Engineering at the University of Mauritius. She holds a Ph.D. in Chemical Engineering. Her research interests are in waste management, bio-gas production and life-cycle assessment.

George Teke Forbid

George Teke Forbid currently teaches various courses in Environmental Sciences, Engineering and Chemistry at the University of Dschang, University of Bamenda, Catholic University of Bamenda and Bamenda University of Science and Technology. He obtained Ph.D. in Environmental Sciences and an M.Sc. in Environmental and Resource Management from the Brandenburg University of Technology (BTU) in Cottbus, Germany. Prior to his studies abroad, he acquired a B.Sc. in Chemistry and B.A. in Psychology from the University of Dschang, Cameroon. In addition, he has a *Diplome de Professeur de l'Enseignement Secondaire Premier Grade*, the equivalent of a B.Ed. in Chemistry Education from the University of Yaounde, Cameroon. He is currently a lecturer, but also serves as a consultant and conducts research in the areas of Environmental and Resource Management, Environmental Impact Assessment, Technology Transfer and Innovation, Environmental Engineering and Appropriate Technology Development, Industrial Safety, Risk and Loss Prevention, Political Ecology, Sustainable Project Management and Entrepreneurship Development.

Günter Busch

Günter Busch is a retired head of the Chair of Waste Management of the Faculty of Environmental Sciences and Process Engineering at Brandenburg University of Technology, Cottbus, Germany. He obtained a Ph.D. in Engineering while lecturing and conducting research at the University of Technology (TUD) in Dresden, Germany. He currently researches, consults and lectures at several universities and for companies around the world. He taught at the University of Addis Ababa, where he created a Department of Chemical Engineering. He has wide practical experience in the acquisition and co-ordination of research projects, research and engineering practice, teaching and consultancy. He has several scientific publications and patents to his credit. He has international teaching and consultancy experience in Germany, Brazil, Mexico, Japan, China, Kazakhstan and Ethiopia. His research interests include bio-gas production and technology development, sustainable waste management and waste-to-energy engineering.

James Okot-Okumu

James Okot-Okumu is an Associate Professor of Environmental Science at Makerere University, Kampala, Uganda, where he has taught courses in Environmental Science that include waste management and sanitation, water resources management, cleaner production and environment and social impact assessment. He studied bio-chemistry and chemistry at the University of Ghana, Legon-Accra, graduating with a B.Sc. (Hons). He obtained a scholarship to study at the then IHE-Delft, now the International Institute for Infrastructural, Hydraulic and Environmental Engineering, Delft, the Netherlands. He obtained a postgraduate diploma in Environmental Science and Technology with distinction, which enabled him to enrol for the Masters' programme in Environmental Science and Technology, specialising in Ecotoxicology. James completed his Ph.D. study at Makerere University.

Jason Samuel Ogola

Jason Samuel Ogola is a Professor Emeritus of Economic Geology/Mining Geology at the University of Venda, South Africa. His areas of research include mineral exploration and mining impacts, with emphasis on tailings dams and waste-rock dumps. He has conducted work on municipal and hospital solid wastes, looking at the dispersion and distribution of heavy metals from such wastes. With more than 40 publications in refereed journals, refereed conference proceedings and book chapters to his name, he has presented some 80 papers at national and international conferences. He has collaborated widely with scholars and academics from Wits University; University of Cape Town; St. Andrews University (Britain); Colorado School of Mines (USA); the

University of Göttingen, Technical University of Clausthal and University of Applied Sciences Ostwestfalen-Lippe (Germany).

Judith Tumusiime Tukahirwa

Judith Tukahirwa Tumusiime is the Deputy Executive Director at Kampala Capital City Authority, Uganda, which is a corporate body mandated by Uganda's central government to deliver public services to the residents and non-residents of Kampala. She plays an oversight role in terms of providing leadership, policy and management decisions, steering technical and strategic planning and the overall supervision of implementation, monitoring and evaluation of all technical programmes and projects (both local and internationally funded) in the areas of Public Health and Environment, Education and Social Services, Gender and Community Development, Engineering Services, and Physical Planning. She holds a Ph.D. in Urban Sanitation and Solid Waste Management from Wageningen University, Netherlands.

Luke Chimuka

Luke Chimuka is a full professor in Environmental Analytical Chemistry at the School of Chemistry at the University of the Witwatersrand, Johannesburg, South Africa. He earned a B.Sc. (Hons) at the University of Zambia, and graduated in 1990. He then worked in the private sector for three years, after which he decided to do his M.Sc. in Analytical Chemistry at the University of Botswana and the University of Bayreuth-Germany, where he graduated in 1996. This was followed by a Ph.D. in Analytical Chemistry at the Lund University, Sweden, obtained in 2001. Between 2001 and 2002 he was a post-doctorate fellow in the School of Chemistry at the University of the Witwatersrand. He then spent three years as senior lecturer, researcher and later Head of Department at the Department of Ecology and Resource Management, School of Environmental Sciences, University of Venda, South Africa.

Martin Oteng-Ababio

Martin Oteng-Ababio is a Senior Lecturer and the Coordinator of the Urban Disaster Risk Reduction Programme in the Department of Geography and Resource Development at the University of Ghana. He holds a Ph.D. in Geography from the University of Ghana. He won the Japanese Award for Outstanding Research on Development for 2011 and Best Paper Award at the Southern Africa Society for Disaster Reduction Conference in 2012. His research interests include urban environmental management; urban disaster risk reduction and informal urbanism. His research works have been published in various journals including *Habitat International*, *Environment and Planning A*, *International Development Planning Review*, *Applied Geography*, *Urban Geography*, and *Journal of Housing and the Built Environment*.

Muhammad Ali Zumar Bundhoo

Muhammad Ali Zumar Bundhoo holds a B.Eng. (Hons) degree in Chemical and Environmental Engineering from the University of Mauritius. He is currently reading for an M.Phil./Ph.D. in the Chemical and Environmental Engineering Department, Faculty of Engineering, at the University of Mauritius. His main research interests include solid waste management technologies such as anaerobic digestion for biological methane production, and dark fermentation processes for bio-hydrogen production. He is fascinated by the use of pre-treatment technologies such as microwave and ultrasound irradiation for enhancing the effectiveness of biological treatment systems and biological energy production.

Najib Bateganya Lukooya

Najib Bateganya Lukooya is an Environmental systems analyst with a track record and experience in research and capacity-building, consultancy work on local and international projects, project planning and implementation and management in water and the environment sector in Africa and Europe. Developing and implementing multi-stakeholder development processes and projects (government, Private sector, Civil society and development partners) in sub-Saharan Africa. Mr Lukooya holds an M.Sc. in Environmental Sciences from UNESCO-IHE, Delft, the Netherlands in Collaboration with the Austrian Academy of Sciences, and is currently a Ph.D. candidate in Natural Resources and Environmental Engineering at the University for Natural Resources and Life Sciences, Vienna, Austria.

Oomesh Gukhool

Oomesh Gukhool is currently a lecturer at the University of Mauritius. He received his B.Sc. (Hons) in Business Information Systems and his Ph.D. in Adaptive Technologies from the University of Technology in Mauritius. His area of research is geared towards modelling and optimising environmental problems. He has provided his expertise in several projects regarding solid waste collection and transportation, as well as formulation of solid waste management models.

Thaddeus Chidi Nzeadibe

Chidi Nzeadibe is a Senior Lecturer in the Department of Geography at the University of Nigeria, Nsukka. He is a Visiting Scholar at the Nordic Africa Institute (NAI), Uppsala, Sweden. He earned a Ph.D. in Environmental Management and has published extensively in journals and other media on solid waste governance, urban poverty and livelihoods within the informal recycling system in Nigerian cities. His current research focuses on urban political ecology, exploring the interconnections

of solid waste with urban governance, the informal economy, and development in Africa.

Trynos Gumbo

Trynos Gumbo is a Senior Lecturer, Department of Town and Regional Planning, University of Johannesburg, South Africa and formerly research specialist in the Sustainable Development Programme at the Africa Institute of South Africa within the Human Sciences Research Council. He holds a Ph.D. in Geography and Environmental Studies from the University of Stellenbosch. He also has M.Sc. and B.Sc. (Hons) degrees in Rural and Urban Planning from the University of Zimbabwe. His research interests include innovations in urban planning, development and management, municipal solid waste management and recovery for renewable energy generation, pollution control and climate change mitigation. He previously lectured at the University of Zimbabwe (UZ), the National University of Science and Technology (NUST) (Zimbabwe) and the Ethiopian Civil Service University College (Ethiopia). He has attended and presented papers at national and international conferences, and has published several articles in refereed journals.

Abbreviations and Acronyms

ACC	Accra City Council
AD	Anaerobic digestion
AEPB	Abuja Environmental Protection Board
AGRESU	Greater Area of Maputo
AMA	Accra Metropolitan Assembly
AMD	Acid mine drainage
ASMARE	Association of Collectors of the Metropolitan Landfill of Jardine Gramacho
BAN	Basel Action Network
CBOs	Community-based organisations
CCC	Community container collection
CCWL	City country waste limited
CDCF	Community development carbon fund
CDM	Clean development mechanism
CERs	Certified emission reductions
COP	Conference of Parties
CP	Cleaner production
CSIR	Council for Scientific and Industrial Research
CSOs	Civil society organisations
CSOs	Central statistics offices
CSR	Corporate social responsibility
DEA	Data envelope analysis
DPHE	Directorate of Public Health and Environment
EAC	East African Community
ECOWAS	Economic Community of West Africa
ED	Executive Director
EDC	Export Development Corporation
EEE	Electrical and electronic equipment
EMA	Environmental Management Act
EMPA	Swiss Federal Laboratories for Materials Testing and Research
EPA	Environmental Protection Agency
EU	European Union

eWASA	e-Waste Association of South Africa
FGDs	Focus group discussions
FIWON	Federation of Informal Workers' Organisations of Nigeria
FoE	Faculty of Engineering
GDP	Gross domestic product
GHG	Greenhouse gas
GTZ	Gesellschaft für Technische Zusammenarbeit
HDI	Human Development Index
HtH	House to house
IFC	International Finance Corporation
INC	Initial national communication
IPWM	Integrated pollution and waste management
ISR	Informal sector recycling
ISWM	Integrated solid waste management
IWM	Informal waste management
KCC	Kampala Capital City
KCCA	Kampala Capital City Authority
KIIs	Key informant interviews
KIWODET	Kisitu Women Development Trust
Las	Local authorities
LAWMA	Lagos State Waste Management Authority
LCA-IWM	Life-cycle assessment integrated waste management
LCIA	Life-cycle impact assessment
LMI	Low medium income
MDGs	Millennium Development Goals
MEHD	Metro Environmental Health Department
MLGRD	Ministry of Local Government and Rural Development
MMDAs	Metropolitan, municipal and district assemblies
MoH	Ministry of Health
MOHD	Medical Officer of Health Department
MoU	Memorandum of Understanding
MRDBH	Ministry of Regional Development, Building and Housing
MRF	Material recovery facilities
MSW	Municipal solid waste
NAI	Nordic Africa Institute
NAS	National Association of Scavengers
NEERI	National Environmental Engineering Research Institute

NEMA	National Environmental Authority
NEMP	National Environmental Management Policy
NEPAD	New Partnership for African Development
NESREA	National Environmental Standards and Regulation's Enforcement Agency
NGOs	Non-governmental organisations
NRM	National Resistance Movement
NWMS	National Waste Management Strategy
OAU	Organisation of African Unity
OECD	Organisation for Economic Co-operation and Development
OR	Operational research
PACSA	Packaging Council of South Africa
PPIAF	Public-Private Infrastructure Advisory Facility
PPPs	Public-private partnerships
RESA	Resource recovery scavenging approach
SIDS	Small Islands Developing States
SLU	Public Cleansing Agency
SMEs	Small and medium-size enterprises
SNC	Second national communication
SW	Solid waste
SWC	Solid waste collection
SWM	Solid waste management
UCs	Urban councils
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Conventions Framework on Climate Change
UNGA	United Nations General Assembly
USA	United States of America
USEPA	United States Environmental Protection Agency
VERs	Verified emission reductions
WEEE	Waste electrical and electronic equipment
WIE	Waste to energy incineration
WIEGO	Women in Informal Employment: Globalising and Organising
WMD	Waste Management Department
WMS	Waste management system
WTE	Waste-to-energy

CHAPTER 1

Introduction

Thokozani Simelane and Romeela Mohee

Green issues have become cohesive factors that surpass divisive socio-economic and political government agendas.¹ One of these issues is municipal solid waste (MSW), and it requires investigation regarding its future use.^{2,3} MSW can be viewed as a component of the environmental management process that has a direct bearing on a city's attractiveness and its social, economic and political development. In legal terms, it is a government service to which every citizen is entitled.^{4,5} First-world countries have made MSW management a priority by adopting strict regulations and innovative measures concerning its use (e.g. energy generation), as well as putting monitoring mechanisms in place that seek to ensure that MSW is included in the development agendas of cities.⁶

Rates and quantities of solid waste generation, composition and disposition vary across Africa, being linked to local economies, levels of industrial development, waste management systems and lifestyles.^{7,8} The quality and availability of data on solid waste generation and management in Africa is, however, scanty if not poor. This impedes the development of programmes that will promote the efficient use of municipal solid waste in Africa. Developing a broader understanding of the types of solid waste generated by African economies and researching how these can be used to advance development is now more than desirable, as solid waste is increasingly seen as an alternative source of renewable energy.

There are several factors that drive MSW management in a country.⁹ It is therefore important to identify these, in order to develop relevant strategies and innovative ways of integrating waste into the development strategy of a city. Devising better management options through the re-use of waste could help Africa achieve the seventh Millennium Development Goal.

However, in order to attain this, there are factors that need urgent attention. These directly or indirectly influence MSW management. They include, among others, natural environmental concerns, social norms and associated concerns, economic factors, historical influences, political contexts, local, regional and national legislation, institutional factors, educational factors, technological developments, human resource deployment and financial constraints. Combined, these bring to the fore challenges associated with the future direction of MSW management.

When it comes to waste management, Africa has a varied historical and political background. There are allegations that some African countries serve as little more than dumping-grounds for toxic and hazardous waste produced, mostly, in the developed world. To some extent this is directly linked to a culture of economic dependency on these countries and the inherent belief that Africa can be used for any purpose, it being rife with the corrupt traditions and practices that are endemic to the continent and which ultimately affect all facets of lifestyles in Africa, not to mention its environmental management practices. Some of the biggest African cities, such as Nairobi (Kenya), Dar Es Salaam (Tanzania), Lagos (Nigeria), Cairo (Egypt) and Johannesburg (South Africa) are experiencing population growth trends fuelled by high rates of migration.¹⁰ This has led to increased production of solid waste in these cities, which in turn has led to some of them losing their attractiveness, because the waste-collection systems of these cities have become inefficient. Generally, in most African cities, proper sanitary landfills are still lacking, and waste is often thrown around in heaps. It is principally for this reason that most African cities are perceived as unhealthy.

By 2020, more than 50 per cent of the population in sub-Saharan Africa will be living in cities.¹¹ This is likely to see daily waste production increasing to as high as 1,0 kg/capita. For instance, the African Environment Outlook estimates that the per capita generation of solid waste averages 0,7 kg/day in Zimbabwe and 1,0 kg/day in Tanzania. Most of these waste products contain a large proportion of organics. Mauritius generates around 1,1 kg/capita/day of mixed MSW, which has increased significantly from 0,8 kg/capita.¹² South Africa has recognised the impact of waste as a major challenge of the twenty-first century in its Integrated Pollution and Waste Management Policy, established by the Department of Environmental Affairs and Tourism.¹³ The policy outlines goals to be achieved through the National Waste Management Strategy,¹⁴ and highlights elements of integrated waste management planning. These include waste information systems, general waste collection, waste minimisation, recycling, waste treatment and disposal, capacity-building, education and awareness as among the key interventions needed to promote the efficient use and management of waste in Africa. According to the 1999 State of the Environment report,¹⁵ South Africa generates over 42 million cubic metres of solid waste every year. In 2001, the amount of waste produced was noted as increasing due to population growth, urbanisation and economic development.

What these dynamics of waste production and management demonstrate is that disparities exist in the volume of waste generation, as well as in management strategies, between higher- and lower-income countries. Higher-income countries generate more waste per capita per year (2,7 m³/capita/year) than lower-income countries (0,2 m³/capita/year).¹⁶ For instance, Accra, Ibadan, Dakar, Abidjan and Lusaka all

generate in the range of 0,5–0,8 kg/capita/day, with a putrescible organic content of 35–80 per cent, with plastics, glass and metals at less than 10 per cent. It is believed that, because of improving standards of living and increased urbanisation, the amount of waste generated by African cities will increase over the coming years. According to Visser & Theron,¹⁷ waste generated in most urban areas in Africa will quadruple by 2025.

In urban centres throughout Africa, less than half of the solid waste generated is collected, and 95 per cent of this is neither contained nor recycled.¹⁸ It is indiscriminately thrown away at dumping sites on the periphery of urban centres, or at temporary sites. These inefficient forms of solid waste disposal have serious health and environmental impacts that extend beyond their boundaries, polluting nearby water sources and serving as breeding grounds for diseases.

In low-income countries, the situation is worse. In Lesotho, for instance, only seven per cent of urban households have garbage collection facilities, while in Gaborone (Botswana) and Maputo (Mozambique), nearly all solid waste is disposed of on an open dump, rather than in a sanitary landfill.¹⁹ Afon reported that in Lagos (Nigeria), heaps of garbage pile up at street-corners and are often dumped indiscriminately.

In spite of these challenges, some African countries have set themselves ambitious goals and targets that seek to implement effective waste management techniques and strategies, so as to promote proper management and disposal of waste. These include recycling, composting and anaerobic digestion. The progress made in these areas and technologies thus far, as well as the methods adopted, is encouraging.

Solid waste management is a significant environmental challenge, especially in large cities. Therefore alternative uses for the waste, such as energy-generation, composting, separation and recycling, which are all capable of converting waste into valuable assets, are desirable so that Africa might catch up with international trends and standards in the management of municipal solid waste. For the continent to attain this, however, a number of hurdles still need to be overcome. These include improving the methods currently used to collect and dispose of waste. As stated earlier, however, the most popular disposal practice in a number of African countries, regrettably, remains unsanitary landfilling or open dumping. This has promoted scavenging, which confers a low social status on those who promote recycling by collecting and re-using waste for various purposes. The lack of advanced methods, supported by appropriate technologies, means that there are very few alternative practical uses of solid waste in Africa. To change this situation, investment in solid waste management and its related technologies needs to be attracted.

This investment should be supported by extensive research into municipal solid waste management that should emphasise:

- natural environmental analysis;
- social norms and concerns analysis;
- analysis of economic factors that promote waste production and management;
- historic influences on waste disposal and management in Africa;
- political contexts of waste management in Africa;
- local, regional and national legislation pertaining to waste management in various countries in Africa;
- institutional factors, including educational factors, which will promote innovative uses of waste in Africa; and
- technological developments for waste re-use and management suitable for African economies and the environment.

Solid waste management is a function that is primarily provided by local governments in most countries, and especially in developing countries.²⁰ However, proper handling and disposal of waste is an indicator of how successfully and effectively the local government system is functioning. Among developed nations, waste is no longer a burden of the state, but a resource that has been integrated into energy-generation strategies. However, as reflected in this volume, it can be argued that waste management and its re-use is reflective of the level of development of most African states. This requires drastic improvement through the adoption of appropriate strategies and the latest technologies.

Notes and References

- 1 Nhamo, G., (ed.), 2011. *Green Economy and Climate Mitigation: Topics of Relevance to Africa*. Pretoria: Africa Institute of South Africa.
- 2 Chevallier, R., 2011. Political barriers to climate change adaptation implementation in SADC. In L. Masters & L. Duff (eds.), *Overcoming Barriers to Climate Change Adaptation Implementation in Southern Africa* (pp.1–20). Pretoria: Africa Institute of South Africa.
- 3 Simelane, T., Kaggwa, M. & Mutanga, S., 2011. Technology barriers to climate change adaptation implementation in the SADC region. In L. Masters & L. Duff (eds.), *Overcoming Barriers to Climate Change Adaptation Implementation in Southern Africa* (pp.183–200). Pretoria: Africa Institute of South Africa.
- 4 Kumar, S. & Khanna, M., 2009. Measurement of environmental efficiency and productivity: A cross-country analysis. *Environment and Development Economics*, 14(4), pp.475–495.
- 5 Fahmi, W. & Sutton, K., 2010. Cairo's contested garbage: Sustainable waste management and the Zabaleen's right to the city. *Sustainability*, 2, pp.1765–1783.
- 6 Nzeadibe, T.C., 2009. Solid waste reforms and informal recycling in Enugu urban area. *Habitat International*, 33, pp.93–99.
- 7 Adedibu, A., 1983. Solid waste characteristics and management in Ilorin. *Journal of the Nigerian Institute of Town Planners*, 3(1), pp.33–41.

- 8 Abel, A., 2007. An analysis of solid waste generation in a traditional African City: the example of Ogbomoso, Nigeria. Available at <http://eau.sagepub.com> [Accessed 28 May 2012].
- 9 Cargo, D.B., 1978. *Solid Wastes: Factors Influencing Generation Rates*, Issue 174. Chicago: University of Chicago, Department of Geography.
- 10 Simelane, T., 2011. Interpreting the transformation of the city centres of South Africa through System Dynamics: How different are they from other African cities? *Africa Insight*, 40(4), pp.168–186.
- 11 Ahmed, S.A. & Ali, M., 2004. Partnerships for solid waste management in developing countries: Linking theories to realities. *Habitat International*, 28, pp.467–479.
- 12 Afon, A., 2007. An analysis of solid waste generation in a traditional African city: The example of Ogbomoso, Nigeria. *Environment and Urbanization*, 19(2), pp.527–536.
- 13 Department of Environmental Affairs and Tourism (DEAT), 2000. White Paper on Integrated Pollution and Waste Management for South Africa. *Government Gazette*, 20978, pp.10–14.
- 14 Department of Environmental Affairs and Tourism (DEAT), 2001. *National Waste Management Strategy (NWMS)*, version D, pp.1–158.
- 15 Department of Environmental Affairs and Tourism (DEAT), 1999. *National Waste Management Strategy Action Plans (NWMSAP)*, version C, pp.1–26.
- 16 Department of Water Affairs & Forestry, 1998. Minimum Requirements for Waste Disposal by Landfill (2ed.), Pretoria: Department of Water Affairs & Forestry, South Africa.
- 17 Visser, M. & Theron, J., 2009. Waste not: Externalisation and the management of waste in Cape Town, *Institute for Poverty, Land and Agrarian Studies (PLAAS) Working Paper 12*. Cape Town: Institute for Poverty, Land and Agrarian Studies.
- 18 Ahmed, S.A. & Ali, M., 2004. Partnerships for solid waste management in developing countries: Linking theories to realities. *Habitat International*, 28, pp.467–479.
- 19 Afon, A., 2005. *Solid waste generation in selected cities of Ogo State, Nigeria* (PhD thesis). Department of Urban and Regional Planning, Obafemi Awolowo University, Ile-Ife, Nigeria.
- 20 Simelane, T & Mohee, R 2012. Future directions of municipal solid waste management in Africa. AISA Brief 88. Africa Institute of South Africa, Pretoria.

CHAPTER 2

A Comparative Analysis of Solid Waste Management in Developed and Developing Countries

Romeela Mohee and Muhammad Ali Zumar Bundhoo

Introduction

Solid waste management (SWM) is one of the major problems faced by the world in terms of the huge amount of waste generated as a consequence of daily human activities.¹ Waste generation is increasing every day, and this is attributed to an increase in population, higher economic development and improving lifestyles.² Furthermore, due to the continued availability of raw materials, items are discarded once broken or used up, with no real need for repair.³ Approximately 1,3 billion tons of municipal solid waste (MSW) is currently being generated worldwide every year, and this figure is expected to double by 2025.⁴ As such, the large amount of waste generated is becoming a growing concern for both developed and developing countries, due to the ecological impact associated with improper waste management, which results in waste degradation and the release of noxious emissions.⁵

Solid waste generation is a global reality, and wastes are handled in different ways in various parts of the world. The main reason for this is the variation in physical characteristics of the waste generated. In developed countries, it is expected that waste composition will tend more toward recyclable materials, while in developing countries the focus is toward organic materials.⁶ Similarly, due to the higher organic matter content in developing countries, the moisture content of the waste is expected to be higher. For this reason, SWM processes differ. The SWM process is not limited to these factors, however, but also depends on the topography of the country, climatic conditions, expertise in the field, the availability of funds, political stability, scavenger activity in the separation of recyclables and the ability, adequacy and constraints of municipalities trying to manage solid wastes (SAIAN cited by Mahar et.al.).⁷

In various countries of the world, therefore, different waste-management practices exist. Best practices include proper composting, recycling, waste-to-energy (WTE) technologies and sanitary landfilling for the ultimate disposal of wastes.⁸ However, other less desirable practices, such as illegal dumping, backyard burning or simple landfilling also exist in many other countries, and these cause severe ecological

problems, not least greenhouse-gas emissions and/or groundwater contamination through leaching, which eventually causes deleterious health effects.⁹

This chapter provides an overview of the solid waste situation in the world, with emphasis on waste-management strategies adopted in other countries. The key functional elements of an integrated solid waste-management (ISWM) system will be analysed and compared for developing and developed countries, together with the legal framework which has been put in place in various countries to deal with solid waste generation. Finally, the generation of MSW and its composition in African countries will be analysed and the current lack of effective waste-management strategies discussed.

Overview of Waste-Management Strategies and Practices

The popular approach to waste management is ISWM. An ISWM system consists of six key functional elements, as illustrated in Table 2.1. First of all, waste is generated, handled, separated, stored and processed at its source. It is then collected by the appropriate authorities and carted away to transfer stations for compaction; to material recovery facilities (MRF) where waste materials are sorted for recycling or composting; or otherwise treated through various waste-to-energy technologies, while the untreated waste fractions are ultimately disposed of in a landfill.

Table 2.1: Functional elements of ISWM

Key functional elements of ISWM	Strategies of the SWM hierarchy
Waste generation	Waste prevention and reduction at source
Waste handling, separation, storage and processing at source	Waste separation and re-use
Waste collection	-
Transfer and transport	-
Waste separation, processing and transformation	Recycling, composting and waste-to energy technologies
Waste disposal	Landfilling

(Adapted from: Tchobanoglous et al, Mohee et al.)

The best scenario is to adopt sustainable steps at each level of the ISWM, as illustrated by the strategies of the SWM hierarchy in Table 2.1. During waste generation, waste prevention and reduction must be emphasised as far as possible. Waste reduction can occur at the manufacturing or consumer level. At the manufacturing level, waste reduction can be accomplished by:¹⁰

1. Modifying the design of products and packages;
2. Reducing the losses and waste produced during the manufacturing process;
3. Material substitution; and
4. Increasing the efficiency of processes through technology change.

At the consumer level, it can be achieved through:¹¹

1. Buying products that are eco-friendly, recyclable and less toxic; and
2. Buying in bulk.

After waste has been generated, it must be source-separated and re-use practices must be developed and encouraged. Re-use of waste refers to the use of the waste materials in their original form, either for the original or a different purpose, without significantly changing the physical form of the materials.¹² After waste collection, these wastes must be separated, if source separation has not yet been done. Once the separation process is complete, recyclable materials (such as plastics, glass and used beverage cans) can be sent to a recycling centre, while other wastes can be subjected either to a composting process or to waste-to-energy technologies (such as anaerobic digestion, incineration, pyrolysis or gasification). Waste that has no end use whatever is ultimately disposed of in a landfill.

Owing to reliable data on waste generation, collection and transportation, as well as proper recycling and final disposal methods, countries with more developed economies have suitable SWM systems in place.¹³ On the other hand, in developing countries, lack of appropriate infrastructure hinders the SWM process. This is becoming a growing concern, due to increased waste being generated by growing populations.¹⁴

Waste Generation Trends

Over the past years rapid industrialisation, coupled with economic development and population growth, has caused a sharp increase in the solid waste being generated in the world.¹⁵ Besides industrialisation and economic development, the recyclable amount, as well as the characteristics of the waste generated, differs from country to country due to varying consumption patterns; lifestyles adopted by individuals; climatic conditions; and waste-management strategies implemented.¹⁶ Solid wastes can be classified into MSW, industrial non-hazardous waste, construction and demolition waste, health-care waste, hazardous waste and sludge, with MSW generally contributing a higher proportion of solid waste.¹⁷

Amount of MSW Generated by Different Economies

A study carried out by Medina¹⁸ revealed that the amount of waste generated in developed countries is much greater than in developing countries. This observation is also confirmed by the data in Table 2.2, with the average MSW generation rate for developing countries being 0,79 kg/capita/day, compared to 1,55 kg/capita/day for developed countries. Individuals in developed countries tend to have a higher income level and a higher standard of living.¹⁹ As disposable incomes and living standards increase, consumption of goods and services also escalate, and this results in an increase in the amount of waste generated.^{20,21} It can also be noted from Table 2.2 that small developing island states (SIDS), such as Fiji and Mauritius, tend to generate high amounts of MSW: 0,94 kg/capita/day (Fiji), and 0,85 kg/capita/day landfilled (Mauritius). The main reason for these high values are that both Fiji and Mauritius are islands, and the huge amounts of waste generated are associated with the tourism industry.²² Furthermore, being SIDS, they import a lot of products. Therefore waste, such as plastic bottles, containers and packaging, is produced, causing an increase in the MSW-generation rate. Finally, it is much easier to account for all waste produced in Fiji and Mauritius, and this contributes to the higher value in MSW-generation rates for these two islands.²³

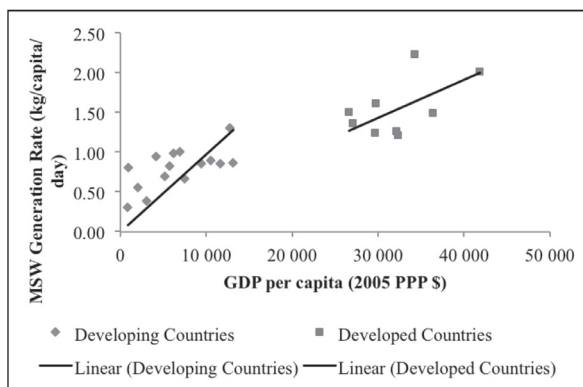
Table 2.2: Gross Domestic Product (GDP), Human Development Index (HDI) and MSW generation rates of selected countries

Country	GDP per capita (2005 PPP \$)a	HDib	MSW generation rate (kg/capita/day)	References for MSW generation rate
Developing countries				
Algeria	7 421	0,698	0,67	Kehila and Gourine ²⁴
Brazil	9 414	0,718	0,85	Troschinetz and Mihelcic ²⁵
Chile	13 057	0,805	0,87	Méndez et al. ²⁶
China	6 200	0,687	0,98	Zhang et al. ²⁷
Egypt	5 151	0,644	0,69	Zaki and Khaya ²⁸
Ethiopia	848	0,363	0,30	Hoornweg and Bhada-Tata ²⁹
Fiji	4 110	0,688	0,94	Grano et al. (cited by Karak et al. ³⁰)
India	2 993	0,547	0,38	Sharholly et al. ³¹
Iran	10 496	0,707	0,89	Troschinetz and Mihelcic ³²
Jamaica	6 931	0,727	1,00	Troschinetz and Mihelcic ³³

Madagascar	912	0,480	0,80	Hoornweg and Bhada-Tata ³⁴
Malaysia	12 724	0,761	1,30	Periathamby et al. ³⁵
Mauritius	11 658	0,728	MSW landfilled rate: 0.85	Statistics: Mauritius ^{36,37}
Nigeria	2 001	0,459	0,55	Ogwueleka ³⁸
Ukraine	5 737	0,729	0,82	IFC ³⁹
Average	-	-	0,79	-
Developed countries				
Australia	34 259	0,929	2,23	Hoornweg and Bhada-Tata ⁴⁰
France	29 578	0,884	1,24	Eurostat ⁴¹
Germany	32 255	0,905	1,22	
Italy	26 578	0,874	1,50	
Japan	29 692	0,901	1,62	Tanaka (cited by Karak et al. ⁴²)
Netherlands	36 358	0,910	1,50	Eurostat ⁴³
Spain	27 066	0,878	1,36	
United Kingdom	32 147	0,863	1,26	
United States	41 761	0,910	2,01	USEPA ⁴⁴
Average	-	-	1,55	-

(Source: ^aData for 2009 (World Bank) and ^bData for 2005–2011 (UNDP))

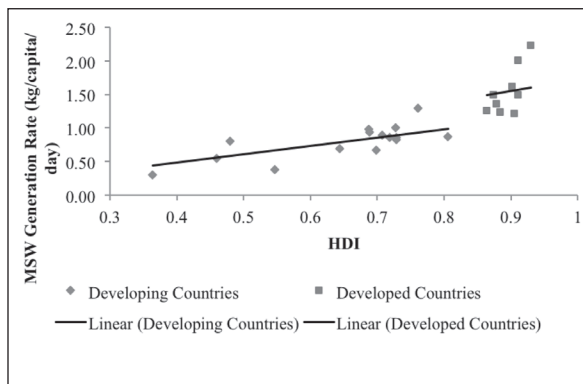
As mentioned previously, many reasons exist for the variation in the amount of waste generated in countries across the world. Among them are economic and political stability; the degree of industrialisation or lack of it; the standard of living; and climatic conditions.⁴⁵ From an economic point of view, the most common term used is GDP per capita, which represents the value of goods and services produced in a country during one year. With a high GDP, a lot of goods and services are produced, and this generates a lot of waste. As such, high GDP can be correlated with high waste generation, as observed in Figure 2.1.

Figure 2.1: Relation between MSW generation rate and GDP per capita

(Compiled from the data in Table 2.2)

For both developing and developed countries, the general trend is that an increase in GDP per capita is followed by an increase in the MSW generation rate. Furthermore, developed countries, having a higher GDP per capita than developing countries, also have a higher MSW generation rate, confirming the relation between GDP per capita and the MSW generation rate.

Besides GDP per capita, the HDI is another indicator that explains the behaviour of MSW generation in various countries. 'HDI is a summary composite index that measures a country's average achievements in three basic aspects of human development: health, knowledge and income'.⁴⁶ As such, HDI relates to the standard of living of an individual, based on health and income. With an increase in HDI, there is an increase in the level of income, as well as an increase in expenditure, which results in an increase in the production of goods and services, as well as in the amount of waste generated.

Figure 2.2: Relation between MSW generation rate and HDI

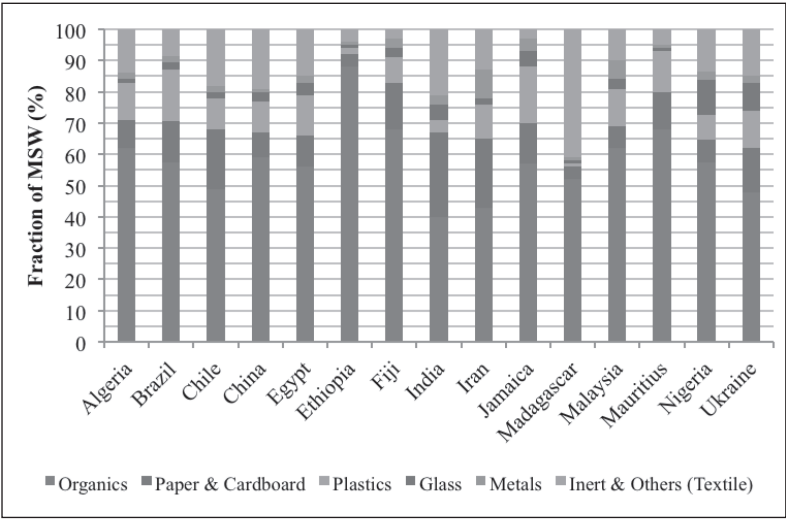
(Compiled from the data in Table 2.2)

As illustrated in Figure 2.2, similarly to GDP per capita, HDI can be correlated with MSW generation rate. With an increase in HDI, an increase in waste generation is observed. Additionally, developed countries have a high level of HDI, resulting in a higher level of waste generation.

Composition of MSW Generated

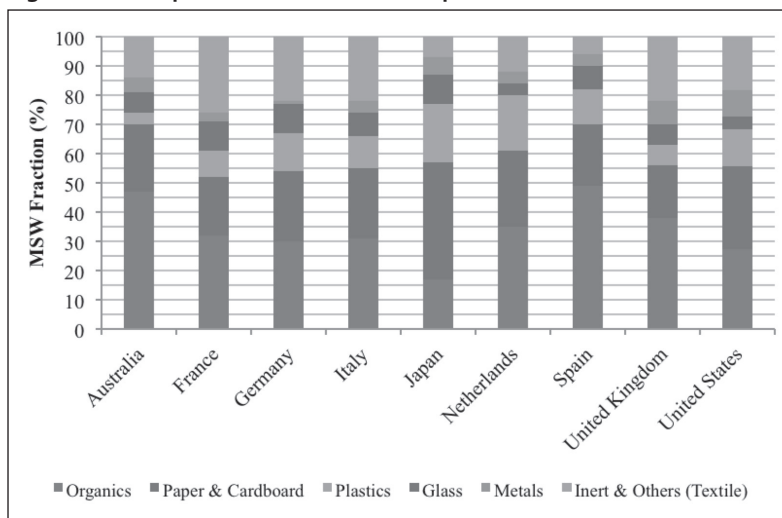
Besides the difference in the quantities of MSW generated, the composition of MSW also differs between developing and developed countries. This variation in the composition of waste generated is also attributed to the consumption pattern of individuals living in developing and developed countries, the lifestyles adopted, and the climates prevailing in various parts of the world. Figures 2.3 and 2.4 illustrate the compositions of MSW generated in selected countries, while Figure 2.5 (a and b) summarises the average MSW composition in developing and developed countries.

Figure 2.3: Composition of MSW in developing countries



(Data obtained from: Mohee, Kehila and Gourine, Zaki and Khayal, Hoornweg and Bhada-Tata, Ayininuola and Muibi, Bianchini and Filho, Estevez, Zhao and Liu (cited by Huang et al.) CPHEEO (cited by IL&FS IDC,) & Breusegem and Stupak,)

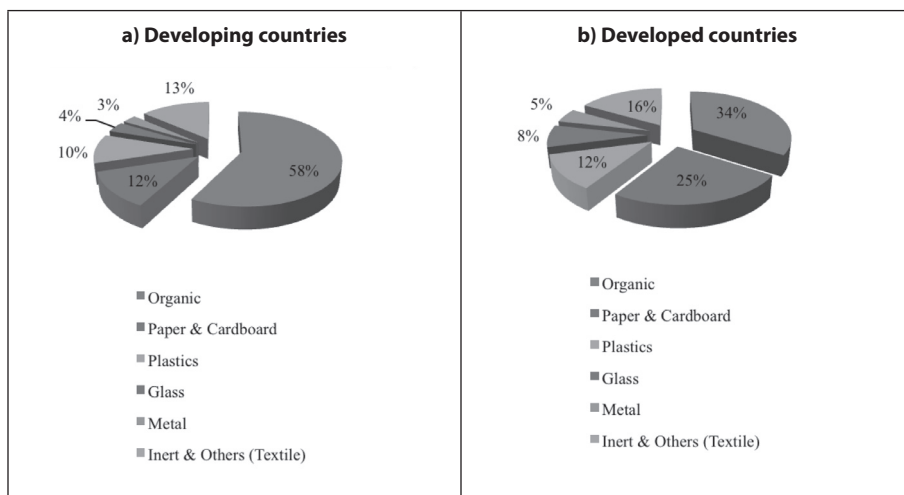
The solid waste composition varies from country to country, especially between developing and developed countries, as illustrated in Figures 2.3 to 2.5. In developing countries (Figures 2.3 and 2.5a), MSW consists mostly of organic material, with an average of 57,8 per cent, followed by recyclable material (paper and cardboard, plastic, glass and metal), with an average of 28,7 per cent.

Figure 2.4: Composition of MSW in developed countries

(Data obtained from: Productivity Commission, Hoornweg and Bhada-Ta ta, Mühle et al., Calabro, Visvanathan, USEPA.)

In developed countries (Figures 2.4 and 2.5b), the quantity of recyclable materials exceeds that of organic ones, with an average of 34,0 per cent organic material and 49,4 per cent recyclables. The lifestyles of individuals in developed and developing countries are the reason for this major difference.^{47, 48} People in developed countries tend to buy ready-made and packaged products, while in developing countries they tend to buy more raw materials, thereby increasing the fraction of organic wastes.^{49, 50} A simple illustration is the consumption of fruit and vegetables. In developed countries, fruit and vegetables are wrapped in plastic and sold, thus generating a lot of plastic after consumption; whereas in developing countries, fruit and vegetables are bought at markets in their raw state. As such, these fruits and vegetables need to be peeled during consumption, generating organic material instead of plastic.

Since waste composition differs between developing and developed countries, the waste-management strategies adopted will, of necessity, also be different. The waste collection systems, waste processing and waste treatment technologies to be employed will vary, based on waste composition and characteristics.

Figure 2.5 (a and b): MSW composition (average) for developing and developed countries

(Compiled from the data in Figures 2.3 and 2.4)

Approaches to Management of Solid Waste

Waste handling, Separation, Storage and Processing at source

Waste handling, separation, storage and processing at source strongly depend on the level of education of citizens, government commitment, financial incentives and proper infrastructure.⁵¹ In developed countries, environmental laws, including land-fill taxes, and local authority involvement are the driving forces behind the existence of waste-handling, separation, storage and processing at source. Illegal dumping is condemned and heavily discouraged by law, and if waste is not properly sorted at source, local authorities will not pick them up. Thus, the residents of developed countries are indirectly forced to adopt the practice of waste segregation at source. Furthermore, the existence of appropriate waste-management frameworks, such as the provision of coloured bins or bags to enable sorting at source, enhances the waste segregation process. With the proper infrastructure in place, people are encouraged to co-operate with local authorities in establishing and maintaining a sustainable waste-management system.

In developing countries, proper waste handling, separation, storage and processing at source are less prevalent than in developed countries.⁵² This is because illegal dumping is widespread, and government incentives are not always available.⁵³ Therefore people are unaware of proper SWM practices. However, with developing countries striving to reach the level of developed countries, the aforementioned incentives (the provision of coloured bags or bins, for example) are now emerging, and

waste-management at source is now more prevalent in some situations. In order to have efficient SWM systems, it is therefore of prime importance to educate people around the globe to be environmentally conscious.

Waste collection

Waste collection is the process of collecting waste from the point of waste generation and transporting it to the point of treatment or disposal, and it is one of the main functional elements of ISWM. There are basically three types of collection systems: human-powered, animal-powered and engine-powered.⁵⁴ In developing countries, planning of a solid waste collection system seems complex, since the waste-management system is invariably designed by consultants from countries with different economic, social and environmental conditions and different waste characteristics^{55,56} In the long run, these experts discontinue their support and the countries are left to manage the increasing amount of SW.⁵⁷ This has incurred a great deal of expense in areas of SWM. In many situations, lack of funds and proper planning has also brought about an obsolete and inefficient collection system.⁵⁸ Table 2.3 shows the MSW collection rates for some developing and developed countries.

Table 2.3: MSW collection rates

Country	Collection rates (%)	Urban /Total
Algeria ^a	92	Urban
Brazil ^a	83	Total
Chile ^b	95	Urban
China (Macao) ^a	100	Total
Egypt ^a	30–95	Urban
Ethiopia ^c	80	Urban
India ^d	72	Total
Jamaica ^a	62	Total
Madagascar ^a	18	Total
Malaysia ^e	80	Total
Mauritius ^a	98	Total
Nigeria ^f	61	Urban

Ukraine ^g	50-70	Total
Average	74,1	–
France ^a	100	Total
Germany ^a	100	Total
Italy ^a	100	Total
Japan ^a	100	Total
Netherlands ^a	100	Total
United Kingdom ^a	100	Total
United States of America ^a	100	Total
Average	100	-

Source: ^aHoorweg and Bhada-Tata, ^bBraütigam et al., ^cPPIAF, ^dNema (cited by Sharholy et al.), ^eLau, ^fNkwocha et al., ^gViguié,

The collection rates in developing countries vary from 18–100 per cent (with an average of 74,1 per cent), while in developed countries the collection rate is 100 per cent, as shown in Table 2.3. Further studies, carried out by Mahar et al.,⁵⁹ revealed that only 51–69 per cent of total waste generated was collected by the authorities in Pakistan; while Medina⁶⁰ argued that less than 50 per cent of the refuse generated in India was collected. Another study, carried out by Muniafu and Otiato,⁶¹ showed that only 25 per cent of the waste generated in Nairobi was collected. Moreover, where payment of waste-disposal fees was required, there was inefficient collection, and municipalities were forced to cut down the collection service in order to reduce the labour force, especially in villages.^{62,63} In various areas in developing countries, irregular collection of solid waste is creating a severe ecological impact.⁶⁴ Additionally, with the infrastructure being hilly, unpaved or narrow in developing countries, waste collection becomes more difficult.^{65,66} This results in a large amount of uncollected waste, and the only option for waste generators is to resort to illegal dumping or backyard burning, again resulting in noxious emissions.

In developed countries, funds available for investment in waste collection areas have brought about a situation where the collection system has greatly improved,⁶⁷ as demonstrated in Table 2.3. Developed countries are able to employ experts in waste collection areas to establish and maintain proper SWM systems.⁶⁸ On the other hand, illegal dumping is prevalent in some developing countries, and a waste collection system is rarely found, as is the case in Madagascar where a waste collection rate of only 18 per cent is achieved.⁶⁹ According to Henry et al.,⁷⁰ a lack of education

and political instability are the two main factors hindering the smooth development of the SWM sector. Additionally, inaccessibility (caused by the lack of roads), a lack of properly designed collection route systems in certain areas, as well as unavailability of bins are further factors impeding waste collection.⁷¹ In some circumstances, communities are deprived of collection services altogether, since the government lacks appropriate resources.⁷²

Transfer and transport of waste

Another functional element of the SWM system is transfer and transport. This involves the transfer of wastes, in appropriate waste-collection vehicles, from the point of waste collection and transportation to a transfer station, MRF or disposal site. In developing countries, there are two common problems involving collection vehicles: either the vehicles used are obsolete, expensive and ineffective; or these obsolete vehicles are substituted with modern compactor trucks that are unsuitable for waste collection in developing countries, and thus represent a waste of money.⁷³ Besides these two factors hampering the efficiency of waste collection in developing countries, poor maintenance of MSW collection vehicles also affects the transportation process, resulting in low collection rates and high levels of illegal dumping.⁷⁴ On the other hand, availability of funds and expertise in SWM in developed countries has enabled a proper transport system to be put in place, where solid wastes are efficiently transported to waste-treatment or disposal sites.⁷⁵

Separation, Processing and Transformation of Solid waste

The separation, processing and transformation of solid wastes depend on government incentives to carry out such processes. In developed countries, the availability of funds and the presence of human expertise to propose appropriate SWM practices have enabled the separation, processing and transformation of solid wastes in special facilities, such as the MRFs already mentioned.⁷⁶ These have been designed to help achieve waste separation, processing and transformation. Sorting is carried out to separate the wastes into various components, such as glass, plastic, metal, rubber and organics, among others. Plastics, glass and aluminium cans are further processed and transformed into bales. These are sent to recycling centres, while organic wastes are sent to a composting plant. Other potential technologies for transforming plastics include waste-to-energy (WTE) facilities such as incineration, pyrolytic and gasification plants; while organic wastes can also be sent to Anaerobic digestion (AD) plants, instead of to composting facilities. In developing countries, MRFs are practically non-existent, due to the lack of finance, the lack of government incentives and the lack of willingness to encourage material recovery.⁷⁷ As such, the practice of recycling, composting, anaerobic digestion and waste-to-energy technologies is far

less frequent in developing countries, while the practice of illegal dumping and open burning is more prevalent.⁷⁸

Landfilling

Landfilling, which refers to the placement of wastes in a landfill, has been the most common practice of waste-management and disposal in various countries of the world, since it represents an economic option to dispose of wastes and is the cheapest method in terms of exploitation and capital costs, according to Renou et al.⁷⁹ However, with emerging WTE technologies, composting, AD and recycling practices, landfilling is decreasing with time. In developed countries, the fraction of MSW being landfilled is in the order of 43 per cent, while in least-developed countries the figure is much higher, at 59 per cent.⁸⁰ The main reason for this difference is the development of other waste-management and treatment technologies in developed countries. Landfills in developed countries are better designed for placement of wastes, as they include better liners, leak detection and leachate collection systems, as well as better gas collection and treatment systems than those in developing countries.⁸¹

Composting

Composting refers to the aerobic degradation of organic waste by micro-organisms in a controlled environment and in the presence of oxygen, to produce a stable end-product, termed compost.⁸² Composting is used mainly for the management of organic wastes and, as such, would be ineffective for the management of MSW high in plastics, metals and glass content. Composting is therefore better suited as a waste-management technology in developing countries, since the organic fraction of MSW is much higher in developing countries than in developed countries, as illustrated in Figure 2.5. However, though this would be the ideal solution, composting is mostly practised in developed countries, rather than in developing ones. In 2009, the fraction of MSW composted in Italy was 35,4 per cent, while in Spain and the Netherlands it was greater than 20 per cent.⁸³ Though some developing countries do adopt composting as a waste-management strategy, the composting process tends to be unsuccessful due to composting of commingled instead of segregated MSW, resulting in poor-quality compost.

Anaerobic digestion

AD refers to the breakdown of organics, in the absence of oxygen, to produce a biogas consisting mainly of methane, carbon dioxide and a digestate of high nutrient value.⁸⁴ The AD process was initially developed as a means to produce biogas and, hence, energy. However, with the abundance of coal and petroleum, AD was mostly used as a waste-water treatment technology, rather than to produce biogas.⁸⁵

Nevertheless, developing countries, such as India and China, continued using the AD process for the production of biogas from manure and other wastes, and are the current reference in terms of AD for developing countries.⁸⁶ As for developed countries, the increasing use of fossil fuels and their continued soaring prices are contributing to the shift towards AD in European countries. In 1990, only three AD plants existed in Europe, with a total capacity of 87 000 tons per annum (tpa), and this has increased to 171 plants in 2010 with a total capacity of 5 204 000 tpa.⁸⁷ As with composting, the high organic fraction in MSW in developing countries is aiding the development and implementation of AD plants, while the high price of fossil fuels assists the development of AD plants in developed countries.

Material recycling

Material recycling is the process of recovery of a waste material for re-use, and the processing thereof into another useful product.⁸⁸ The most commonly recycled materials include used plastics, paper, cardboard and metals, such as used beverage cans and glass, etc. These materials are processed into bales at a material recovery facility, prior to being recycled into new products at recycling plants. Waste recycling has mostly been practised in developed countries, and is only now emerging in developing countries. In developed countries, the fraction of recyclables in MSW is much higher than in developing countries, as summarised in Figure 2.5 (a and b). As such, recycling is a better waste-management option in developed countries than in developing ones. In 2010, Japan increased its plastics recycling rate from 73 per cent in 2006 to 77 per cent, and now leads the global plastics recycling race.⁸⁹ This has been made possible with the passing of recycling laws forcing businesses and companies to separate their plastic wastes.⁹⁰ With high-technology sorting and processing facilities, such as MRFs, the recycling rate has been enhanced in developed countries.⁹¹ Besides Japan, other developed countries with high recycling rates include Germany (where 45,0 per cent of MSW was recycled in 2007)⁹² and Australia (where 30,3 per cent of MSW was recycled in 2003).⁹³ Recycling rates in developing countries are much lower than those in developed countries due to the lack of appropriate facilities such as MRFs and a lack of commitment, willingness and regulations aimed at encouraging recycling.⁹⁴ In Mauritius, for instance, the fraction of MSW recycled was 2,9 per cent in 2009,⁹⁵ while in Malaysia the recycling rate is five per cent.⁹⁶

Incineration

Incineration, without energy recovery, is practised with the sole aim of reducing the overall volume of wastes, resulting in a lower quantity of ash to be landfilled. Incineration has been found to reduce the volume of MSW by 90 per cent, and the weight by 75 per cent.⁹⁷ On the other hand, incineration technologies with energy

recovery are used to reduce the volume of wastes, while also harnessing the energy released. Incineration is practised mostly in developed countries, due to their financial ability to run the process.⁹⁸ The United Kingdom, for instance, boasts 60 incinerators,⁹⁹ of which 13 burn MSW, while two use refuse-derived fuels.¹⁰⁰ Incineration is less prevalent in developing countries, and emission-control strategies are less advanced than in developed areas.¹⁰¹ High emission controls result in high operational costs, almost three times higher than the landfilling cost per ton of waste,¹⁰² and this is the main reason for the low presence of incineration in developing countries. Incineration without proper emission control is discouraged, as is the open-burning of wastes, due to the high volume of uncontrolled noxious emissions contributing to air pollution.

Waste disposal

Disposal is the ultimate fate of all waste. Disposal should be adopted only when none of the aforementioned technologies can be implemented, and waste disposal should be done in appropriate sanitary landfills to minimise all their environmental and ecological impacts. Developed countries have specific procedures for the proper disposal of solid wastes. For instance, workable legislation, regulations and action plans are present in developed countries.¹⁰³ Due to a lack of space in these countries, landfilling is carried out only for those wastes that cannot be recycled or used in waste-to-energy technologies; especially incineration.¹⁰⁴ Additionally, owing to availability of funding, much emphasis is laid on the three R's – namely reduce, re-use and recycle – in order to decrease the amount of solid wastes going to the landfill.¹⁰⁵ As such, the 'waste-management hierarchy', namely minimisation, recovery and transformation, and ultimate land disposal has been employed by most developed countries as the basis for developing appropriate SWM strategies.¹⁰⁶

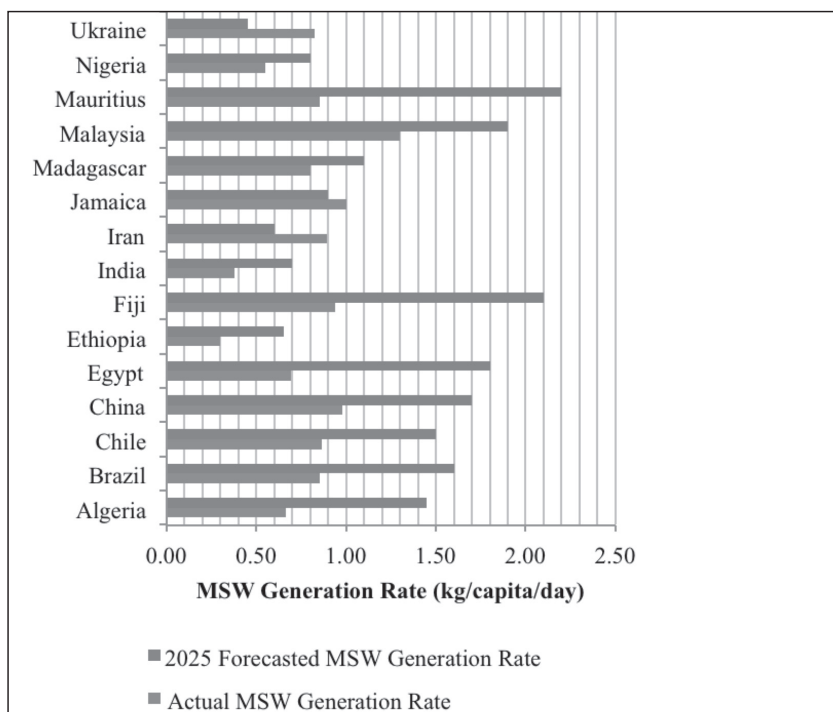
In developing countries there are irregular collections, informal scavenging activities, illegal open dumping and uncontrolled burning to reduce the volume of wastes.¹⁰⁷ The main reasons for these poor practices include, among other things, lack of education, poverty, lack of an appropriate infrastructure and regulations, and very little or no government willingness to implement a proper waste-management strategy.¹⁰⁸ In many cases there are open-dumping, open-burning and improper sanitary landfills.¹⁰⁹ Medina¹¹⁰ studied the problems of waste-management in third-world cities, and reported that 90 per cent of MSW collected ended up in open dumps. Of the small amount of wastes collected, only a small fraction received proper disposal, while the remaining fraction was improperly disposed of, resulting in severe ecological and health effects.¹¹¹ Regassa et al.¹¹² also revealed the problem of illegal dumps, and reported that 74,6 per cent of the respondents in a study said that they carried out burning of organic wastes in pits prepared for such purposes. However,

Mahar et al.¹¹⁵ argued that disposal and treatment technologies, such as engineered sanitary landfill, composting and incineration, were now emerging in developing countries and that the problem of dumps was decreasing with the introduction of proper regulations and infrastructure.

Forecast in MSW Generation

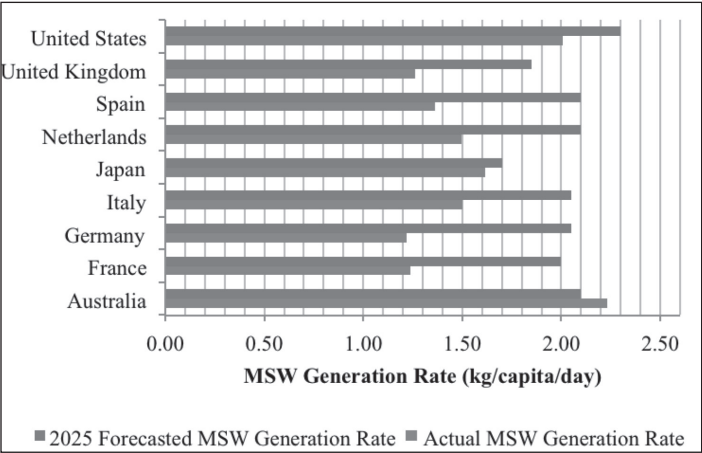
In line with the above, it can be deduced that a proper waste-management system is dependent on various factors, such as government incentives, proper infrastructure, applicable laws and regulations and public awareness and willingness. Additionally, to ensure that current waste-management strategies and treatment technologies continue to operate effectively and that they are in line with any future changes in waste generation rates, a forecast of anticipated waste generation is of utmost importance. With this forecast, waste-management strategies will be better planned in advance and can be adapted to any unforeseen circumstances. Figures 2.6–2.8 provide forecasts of the MSW generation rate by 2025 in various countries.

Figure 2.6: MSW generation rate and forecast by year 2025 for developing countries



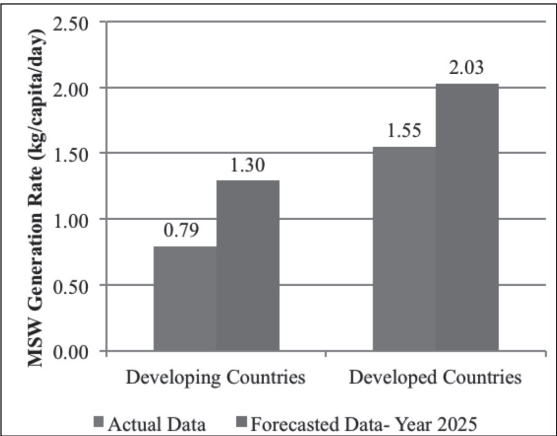
(Data obtained from: Kehila and Gourine, Troschinetz and Mihelcic, Méndez et al., Zhang et al., Zaki and Khayal, Hoornweg and Bhada-Tata, Grano et al., (cited by Karak et al.) Sharholly et al., Periathamby et al., Statistics Mauritius, Ogwueleka, & IFC.)

Figure 2.7: MSW generation rate and forecast by 2025 for developed countries



(Data obtained from: Hoornweg and Bhada-Tata, Eurostat, Tanaka (cited by Karak et al.) & USEPA)

Figure 2.8: MSW generation rate (actual versus forecasted data) for developing and developed countries



(Compiled from the data in Figures 2.6 and 2.7)

As can be observed in Figure 2.8, the MSW generation rate is expected to increase from 0,79 to 1,30 kg/capita/day, representing an increase of 63,58 per cent by 2025 for developing countries. As in developed countries, the generation rate is expected to increase from 1,55 to 2,03 kg/capita/day, representing an increase of only 30,96 per cent by 2025. The most obvious reason for the expected increase in the MSW generation rate, for both developed and developing countries, is the income-level increase of individuals and a higher standard of living. As the spending power of individuals increases, consumption of goods and services increases, causing a hike

in the amount of waste generated. However, the expected increase in the MSW generation rate for developing countries is higher than that for developed countries. This is because developed countries already enjoy high levels of income, standard of living, HDI and GDP per capita. Since the increase in all these factors by 2025 is expected to be lower than in developing countries, this results in a smaller change in the forecasted MSW generation rate for developed countries for 2025.

Regulatory Framework

As mentioned previously, SWM strategies vary from developed to developing countries due to various factors, including the absence of a proper regulatory framework in developing countries. However, as these countries develop further, proper legislation and laws are being enforced on solid-waste generators and, as such, a better waste-management strategy is developed. Table 2.4 summarises some of the acts governing solid wastes in the world.

Table 2.4: Laws governing solid wastes in selected countries

Country	Acts/Laws	Year enacted	Source
Developing countries			
Brazil	National solid waste policy	2010	Da Costa ¹¹⁴
Chile	General Environmental Law	1994	National Commission of the Environment ¹¹⁵
China	Prevention and Control of Solid Waste Pollution	1996	Wang ¹¹⁶
Egypt	Law No. 38/1967 on General Public Cleaning	1967	Zaki and Khayal ¹¹⁷
	Law No. 4/1994 for the Protection of the Environment and their amendments	1994	
Ethiopia	SWM Proclamation no 513/2007	2007	Rogero ¹¹⁸
Fiji	Environmental Management Act 2005	2005	Sheppard ¹¹⁹
	Waste and Pollution Regulations 2008	2008	
India	Environment Protection Act 1986	1986	CED ¹²⁰
Iran	Waste-management Act	2003	Gilani-Lempges ¹²¹
Jamaica	National SWM Act 2002	2002	ELAW ¹²²

Malaysia	Solid Waste and Public Cleansing Management Act 2007	2007	Yahaya ¹²³
Mauritius	Environment Protection Act 2002	2002	Kowlessier ¹²⁴
Nigeria	The National Environmental Standards and Regulations Enforcement Agency ACT 2007 (NESREA ACT)	2007	ELRI ¹²⁵
Ukraine	National Law on Waste	1998	Klean Industries ¹²⁶
Developed countries			
Australia	Environment Protection Act 1993	1993	EPA ¹²⁷
Germany	Waste Avoidance and Waste Management Act	1986	NREL ¹²⁸
Italy	Waste Act (Legislative decree 22/97)	1997	Cesari ¹²⁹
Japan	Basic law for establishing the recycle-oriented society	2000	Yamamoto ¹³⁰
Netherlands	Environmental Management Act 1993 (EMA)	1993	Johnson ¹³¹
Spain	Law 10/1998 on waste	1998	Huerta et al. ¹³²
United Kingdom	EU Waste Framework Directive	2008	DEFRA ¹³³
United States	Solid Waste Disposal Act 1965	1965	Johnson ¹³⁴
	Resource Recovery Act 1970	1970	

Most of the countries in Table 2.4 have appropriate Acts governing SWM. Under each of these Acts, various regulations exist that target specific areas of SWM. In Mauritius, for instance, under that country's Environment Protection Act (2002), there are: the Dumping and Waste Carrier Regulations (2003); the Standards for Hazardous Waste Regulations (2001); and the Industrial Waste Audit Regulations (2008).¹³⁵ Similarly, in India, the Environment Protection Act (1986) consists of various regulations, such as: Bio-medical waste (management and handling) rules (1998); MSW (management and handling) rules (2000); Plastic waste (management and handling) rules (2011) and E-waste (management and handling) rules (2011).¹³⁶

Case Study – Africa

As mentioned previously, solid waste generation remains an unsolved problem in various countries across the world. In Africa, this has been observed to be more pronounced, due to the lack of appropriate waste-management strategies in most African countries.

MSW Generation in Africa

Waste generation and management strategies differ across African countries due to various factors, such as the level of economic development, standard of living, availability of funding, political stability, willingness and waste-management regulations, as mentioned.¹³⁷ Generally, MSW generation rates are quite low for African countries, with the exception of Comoros and Seychelles, where the generation rates exceed 2 kg/capita/day.¹³⁸ Most African countries are classified as low-income (LI) or low medium-income (LMI) economies. As such, with a low level of income and standard of living, the consumption of goods and services is low too, resulting in a decrease in the amount of waste generated. For Comoros and Seychelles, MSW generation rates are comparatively high: 2,23 kg/capita/day¹³⁹ (Comoros); and 2,98 kg/capita/day (Seychelles).¹⁴⁰ The main reason for these high values is that these two African countries are islands, and the huge amount of waste generated is associated with the tourism industry.¹⁴¹ Additionally, being islands, a more complete accounting of all wastes generated can be obtained, contributing to the high MSW-generation rates.¹⁴² Furthermore, being SIDS, these islands import many products, and hence generate a high quantity of waste. With rapid urbanisation, industrialisation and modernisation of agriculture, most African countries are approaching development and moving from lower-income and lower middle-income economies towards upper medium-income (UMI) economies.¹⁴³ The resulting increases in income levels of individuals and higher standards of living cause an escalation in disposable income, as well as consumption of goods and services, and this is expected to result in an increase in the amount of wastes generated.¹⁴⁴

MSW Composition in Africa

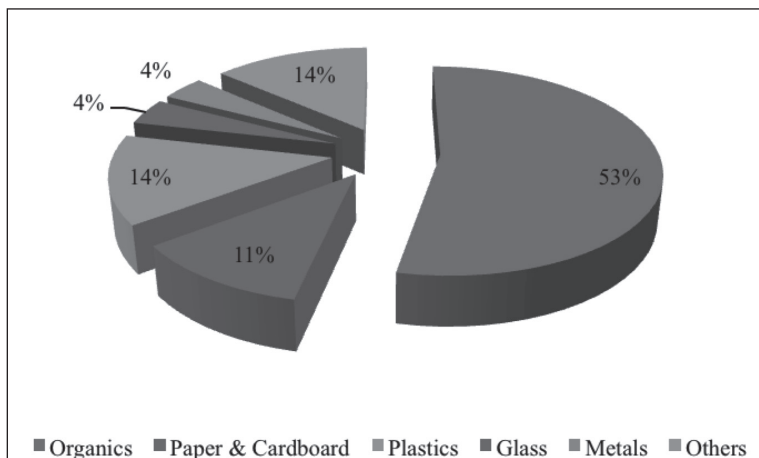
Due to a lack of data for all African countries, the waste composition for selected African countries only is illustrated in Table 2.5 and Figure 2.9.

Table 2.5: MSW composition for selected countries in Africa

Country	MSW components						References
	Organics (%)	Paper & cardboard (%)	Plastics (%)	Glass (%)	Metals (%)	Others (%)	
Algeria	62,0	9,0	12,0	1,0	2,0	14,0	Kehila and Gourine ¹⁴⁵
Botswana	67,9	12,5	4,5	6,4	6,2	2,5	Bolaane and Ali (cited by Karak et al. ¹⁴⁶)

Cameroon	54,8	12,5	12,4	1,6	2,4	16,3	Manga et al. (cited Karak et al. ¹⁴⁷)
Egypt	56,0	10,0	13,0	4,0	2,0	15,0	Zaki and Khayal ¹⁴⁸
Ghana	67,0*	3,0	4,0	0,0	1,0	25,0	WMD-KMA (cited Asase et al. ¹⁴⁹)
Guinea	69,0	4,1	22,8	0,3	1,4	2,4	Matejka et al. (cited Karak et al. ¹⁵⁰)
Kenya	58,2*	17,3	11,8	2,3	2,6	7,8	SLR Consulting Ltd. (cited Couth and Trois ¹⁵¹)
Mali	36,2	12,8	16,0	12,0	14,0	9,0	Samake et al. (cited Karak et al. ¹⁵²)
Mauritania	5,0	6,0	20,0	4,0	4,0	61,0	Mohamed ¹⁵³
Mauritius	68,0	12,0	13,0	1,0	1,0	5,0	Mohee ¹⁵⁴
Morocco	65,0	8,0	10,0	2,0	1,0	14,0	Bouchareb ¹⁵⁵
Mozambique	48,0*	7,5	7,0	2,5	1,5	33,5	SLR Consulting Ltd. (cited Couth and Trois ¹⁵⁶)
Namibia	36,0*	20,0	16,0	13,0	5,0	10,0	SLR Consulting Ltd. (cited Couth and Trois ¹⁵⁷)
Nigeria	57,5	7,1	7,9	11,3	2,6	13,6	Ayininuola and Muibji ¹⁵⁸
South Africa	22,3	24,8	31,5	7,0	6,1	8,3	Trois and Simelane ¹⁵⁹
Tanzania	55,0	9,0	24,0	1,0	8,0	3,0	Kaseva and Moirana ¹⁶⁰
Tunisia	68,0	9,0	11,0	2,0	2,0	8,0	Labidji ¹⁶¹
Uganda	81,8*	5,4	1,6	0,9	3,1	7,2	SLR Consulting Ltd. (cited Couth and Trois ¹⁶²)
Zimbabwe	36,0*	27,0	23,0	5,0	6,0	3,0	Manyanhaire et al. ¹⁶³
Average	53,4	11,4	13,8	4,1	3,8	13,6	-

* Includes wood.

Figure 2.9: MSW composition for Africa (average)

(Compiled based on data from Table 2.5)

As depicted in Table 2.5 and Figure 2.9, the major fraction of MSW generated in African countries is organic, making MSW suitable for either composting or AD processes. The main reason for the high fraction of organic matter in MSW in African countries is the lifestyles adopted by most Africans, with the purchase and consumption of raw materials being favoured over ready-made and packaged products.¹⁶⁴ This results in higher generation of organic materials instead of recyclable materials, such as paper and plastic.

MSWM and Disposal Practices in Africa

We have already mentioned that African countries have poor waste-management practices, due to a lack of education, poverty, inappropriate infrastructure and regulations, as well as low government willingness to implement proper waste-management strategies.¹⁶⁵ Waste collection, one of the key functional elements of the waste-management strategy, is still overlooked in Africa, with MSW collection rates ranging from 20 per cent to 80 per cent, as opposed to 100 per cent in developed countries.^{166,167} Apart from waste collection, proper waste treatment and disposal practices are almost non-existent in African countries. Algeria, for instance, dumps 80 per cent of its MSW,¹⁶⁸ while Egypt dumps 83,5 per cent of MSW generated.¹⁶⁹ Besides dumping, landfilling is frequently practised in African countries, with Madagascar and Mauritius landfills accounting for 97 and 91 per cent of their MSW, respectively.¹⁷⁰ Tunisia landfills 65 per cent of its MSW,¹⁷¹ while Mauritania and Morocco landfill 37,3 and 28 per cent of their MSW, respectively.^{172,173} However, as these African countries move toward becoming more developed countries, proper disposal and treatment technologies are now emerging and this, together with the introduction of

proper regulations and infrastructure, will slowly decrease the amount of MSW being illegally dumped, while increasing the amount of wastes subjected to recycling, composting or WTE technologies.

Conclusion

Solid waste remains a perpetual problem in both developing and developed countries, due to the increasing amount of solid wastes being generated yearly. MSW generation averages 0,79 kg/capita/day in developing countries and 1,55 kg/capita/day in developed countries, due to high GDP and HDI in developed countries. The MSW composition in developing countries, as well as African countries, consists mostly of organic materials, while MSW in developed countries consists mainly of recyclable materials. As such, MSW from developing and African countries is mostly adapted to biological treatment systems, such as composting and AD, while MSW from developed countries is mostly suited to recycling and waste-to-energy technologies such as incineration, pyrolysis or gasification. SWM systems in developing and African countries are fewer in comparison to developed countries, due to the lack of infrastructure, resources, expertise and know-how in waste management, as mentioned. Nevertheless, as developing and African countries are continuously emerging and approaching the standard of living of developed countries, necessary regulatory frameworks governing SWM will need to be set-up to solve the problem of increasing solid wastes generation in developing and African countries.

Notes and References

- 1 Regassa, N., Sundara, R.D. & Seboka, B.B., 2011. Challenges and Opportunities in Municipal Solid Waste Management: The Case of Addis Ababa City, Central Ethiopia. *Journal of Human Ecology*, 33, pp.179–190.
- 2 Minghua, Z., Xiumin, F., Rovetta, A., Qichang, H., Vincentini, F., Bingkai, L., Giusti, A. & Yi, L., 2009. Municipal solid waste management in Pudong New Area, China. *Waste Management*, 29, pp.1227–1233.
- 3 Muniafu, M. & Otiato, E., 2010. Solid waste management in Nairobi, Kenya. A case for emerging economies. *Journal of Language, Technology & Entrepreneurship in Africa*, 2, pp.342–350.
- 4 Gardner, G., 2012. Municipal Solid Waste Growing. In The Worldwatch Institute, Vital Signs (20ed.). Washington: Worldwatch Institute.
- 5 Karak, T., Bhagat, R.M. & Bhattacharyya, P., 2012. Municipal Solid Waste Generation, Composition, and Management: The World Scenario. *Critical Reviews in Environmental Science and Technology*, 42(15), pp.1509–1630.
- 6 Chandrappa, R. & Das, D.B., 2012. Waste quantities and characteristics. In: R. Chandrappa & D.B. Das (eds.), *Solid Waste Management, Principles and Practice*. Heidelberg: Springer-Verlag.

- 7 Mahar, A., Malik, R.N., Qadir, A., Ahmed, T., Khan, Z. & Khan, M.A., 2007. *Review and Analysis of Current Solid Waste Management Situation in Urban Areas of Pakistan*. Proceedings of the International Conference on Sustainable Solid Waste Management. 5–7 September 2007. Chennai, India.
- 8 Guerrero, L.A., Maas, G. & Hogland, W., 2013. Solid waste management challenges for cities in developing countries. *Waste Management*, 33(1), pp.220–232.
- 9 Karak, T., Bhagat, R.M. & Bhattacharyya, P., 2012.
- 10 US EPA. 1995. Decision Maker's Guide to Solid Waste Management, (vol. 2): Source Reduction. *US EPA*. Available at: <http://www.epa.gov/osw/nonhaz/municipal/dmg2/chapter5.pdf> [Accessed 30 July 2014].
- 11 Ibid.
- 12 Tchobanoglous, G., Theisen, H. & Vigil, S.A., 1993.
- 13 Akinci, G., Guven, E.D. & Gok, G., 2012. Evaluation of waste management options and resource conservation potentials according to the waste characteristics and household income: A case study in Aegean Region, Turkey. *Resources, Conservation and Recycling*, 58, pp.114–124.
- 14 Ibid.
- 15 Joseph, K. & Nagendran, R., 2007. *Top down and bottom up approach for sustainability of waste management in developing countries*. Proceedings Sardinia, Eleventh International Waste Management and Landfill Symposium. 1–5 October 2007. Cagliari, Italy: CISA, Environmental Sanitary Engineering Centre.
- 16 Chandrappa, R. & Das, D.B., 2012.
- 17 Mohee, R., Karagiannidis, A., Themelis, N. & Kontogianni, S.T., 2010. *The mounting problems with managing wastes in rapidly developing islands: The Mauritius case*. Third International Symposium on Energy from Biomass and Waste. 8–11 November 2010. Venice: Environmental Sanitary Engineering Centre.
- 18 Medina, M., 2011. Municipal Solid Waste Management in Third World Cities: Lessons Learned and a Proposal for Improvement. *Human Settlement Development*, 3.
- 19 Ibid.
- 20 Chen, C.C., 2010. Spatial inequality in municipal solid waste disposal across regions in developing countries. *International Journal of Environmental Science and Technology*, 7, pp. 447–456.
- 21 Khajuria, A., Yanamoto, Y. & Morioka, T., 2010. Estimation of municipal solid waste generation and landfill area in Asian developing countries. *Journal of Environmental Biology*, 31, pp. 649–654.
- 22 Hoornweg, D. & Bhada-Tata, P., 2012. *What a Waste: A Global Review of Solid Waste Management* (Urban Development Series Knowledge Papers no. 15). Washington: World Bank.
- 23 Ibid.
- 24 Kehila, Y. & Gourine, L., 2010. Country report on the solid waste management in Algeria. The regional solid waste exchange of information and expertise network in Mashreq and Maghreb countries. *SWEEP-Net*. Available at: <http://www.sweep-net.org/country/algeria> [Accessed 26 March 2013].
- 25 Troschinetz, A.M. & Mihelcic, J.R., 2009. Sustainable recycling of municipal solid waste in developing countries. *Waste Management*, 29, pp.915–923.

- 26 Méndez, A.P., Ridao, A.R. & Toro, M.Z., 2008. Environmental diagnosis and planning actions for municipal waste landfills in Estado Lara (Venezuela). *Renewable Sustainable Energy Reviews*, 12, pp.752–771.
- 27 Zhang, D.Q., Tan, S.K. & Gersberg, R.M., 2010. Municipal solid waste management in China: Status, problems and challenges. *Journal of Environmental Management*, 91, pp.1623–1633.
- 28 Zaki, T. & Khayal, A., 2010. Country report on the solid waste management in Egypt. *SWEEP-Net*. Available at: <http://www.sweep-net.org/country/algeria> [Accessed 26 March 2013].
- 29 Hoornweg, D. & Bhada-Tata, P., 2012.
- 30 Karak, T., Bhagat, R.M. & Bhattacharyya, P., 2012.
- 31 Sharholy, M., Ahmad, K., Mahmood, G. & Trivedi, R.C., 2008. Municipal solid waste management in Indian cities: A review. *Waste Management*, 28, pp.459–467.
- 32 Troschinetz, A.M. & Mihelcic, J.R., 2009.
- 33 Ibid.
- 34 Hoornweg, D. & Bhada-Tata, P., 2012.
- 35 Periatnamby, A., Hamid, F.S. & Khidzir, K., 2009. Evolution of solid waste management in Malaysia: Impacts and implications of the solid waste bill. *Journal of Material Cycles and Waste Management*, 11, pp.96–103.
- 36 Statistics Mauritius. 2013. Digest of Demographic Statistics 2012. *Statistics Mauritius*, August 2013. Available at: <http://statsmauritius.gov.mu/English/Documents/demography2012.pdf> [Accessed 5 July 2014].
- 37 Statistics Mauritius. 2013. Environment Statistics 2012. *Statistics Mauritius*, July 2013. Available at: <http://statsmauritius.gov.mu/English/Publications/Pages/Environment-Statistics-2012.aspx> [Accessed 5 July 2014].
- 38 Ogwueleka, T.C., 2009. Municipal solid waste characteristics and management in Nigeria. *Iranian Journal of Environmental Health Science and Engineering*, 6, pp.173–180.
- 39 IFC, 2012. *Municipal Solid Waste Management: Opportunities for Ukraine*. Washington: IFC. Available at: <http://www.ifc.org/wps/wcm/connect/31b3d8004bc75c31b99dff1be6561834/PublicationUkraineMSW2012en.pdf?MOD=AJPERES> [Accessed 5 July 2014].
- 40 Hoornweg, D. & Bhada-Tata, P., 2012.
- 41 Eurostat. 2012. Generation of Waste: Household. *Eurostat*. Available at: <http://appsso.eurostat.ec.europa.eu/nui/submitModifiedQuery.do> [Accessed 28 March 2012].
- 42 Karak, T., Bhagat, R.M. & Bhattacharyya, P., 2012.
- 43 Eurostat, 2012.
- 44 USEPA. 2011. *Municipal Solid Waste Generation, Recycling and Disposal in the United States: Facts and Figures for 2010*. Washington: United States Environmental Protection Agency.
- 45 Minghua, Z., Xiumin, F., Rovetta, A., Qichang, H., Vincentini, F., Bingkai, L., Giusti, A. & Yi, L., 2009.
- 46 UNDP. 2011.
- 47 Calabro, P.S., 2009. Greenhouse gases emission from municipal waste-management: The role of separate collection. *Waste Management*, 29, p.2180.
- 48 Minghua, Z., Xiumin, F., Rovetta, A., Qichang, H., Vincentini, F., Bingkai, L., Giusti, A. & Yi, L., 2009.
- 49 Chandrappa, R. & Das, D.B., 2012.

- 50 Metin, E., Eröztürk, A. & Neyim, C., 2003. Solid waste management practices and review of recovery and recycling operations in Turkey. *Waste Management*, 23, pp.425–432.
- 51 Muniafu, M. & Otiato, E., 2010.
- 52 Regassa, N., Sundara, R.D. & Seboka, B.B., 2011.
- 53 Ibid.
- 54 Ibid.
- 55 Ibid.
- 56 Dhokhikah, Y. & Trihadiningrum, Y., 2012. Solid Waste Management in Asian Developing Countries: Challenges and Opportunities. *Journal of Applied Environmental and Biological Sciences*, 2(7), pp.329–335.
- 57 Muniafu, M. & Otiato, E., 2010.
- 58 Ibid.
- 59 Coffey, M. & Coad, A., 2010. *Collection of Municipal Solid Wastes in Developing Countries*. Kenya: United Nations Human Settlements Programme.
- 60 Mahar, A., Malik, R.N., Qadir, A., Ahmed, T., Khan, Z. & Khan, M.A., 2007.
- 61 Medina, M., 2011.
- 62 Muniafu, M. & Otiato, E., 2010.
- 63 Medina, M., 2011.
- 64 Al-Khatib, I.A., Arafat, H.A., Basheer, T., Shawahneh, H., Salahar, A., Eid, J. & Ali, W., 2007. Trends and problems of solid waste management in developing countries: A case study in seven Palestinian districts. *Waste Management*, 27, pp.1910–1919.
- 65 Ejaz, N. & Janjua, N.S., 2012. Solid Waste Management Issues in Small Towns of Developing World: A Case Study of Taxila City. *International Journal of Environmental Science and Development*, 3(2), pp.167–171.
- 66 Medina, M., 2011.
- 67 Dhokhikah, Y. & Trihadiningrum, Y., 2012.
- 68 Medina, M., 2011.
- 69 Ibid.
- 70 Hoornweg, D. & Bhada-Tata, P., 2012.
- 71 Henry, R.K., Yongsheng, Z. & Jun, D., 2006. Municipal solid waste management challenges in developing countries–Kenyan case study. *Waste Management*, 26(1), pp.92–100.
- 72 Regassa, N., Sundara, R.D. & Seboka, B.B., 2011.
- 73 Ibid.
- 74 Coffey, M. & Coad, A., 2010.
- 75 Henry, R.K., Yongsheng, Z. & Jun, D., 2006.
- 76 Medina, M., 2011.
- 77 Ibid.
- 78 Regassa, N., Sundara, R.D. & Seboka, B.B., 2011.
- 79 Mahar, A., Malik, R.N., Qadir, A., Ahmed, T., Khan, Z. & Khan, M.A., 2007.
- 80 Renou, S., Givaudan, J.G., Poulain, S., Dirassouyan, F. & Moulin, P., 2008. Landfill leachate treatment: Review and opportunity. *Journal of Hazardous Materials*, 150, pp.468–493.
- 81 Hoornweg, D. & Bhada-Tata, P., 2012.
- 82 Ibid.
- 83 Kumar, V.R.S., Sivakumar, K., Purushothaman, M.R., Natarajan, A. & Amanullah, M.M., 2007. Chemical changes during composting of dead birds with caged layer manure. *Journal of Applied Sciences Research*, 3(10), pp.1100–1104.

- 84 UNSD. 2011. Environmental Indicators: Waste. *UNSD*, March 2011. Available at: <https://unstats.un.org/unsd/environment/wastetreatment.htm> [Accessed 7 July 2014].
- 85 Appels, L., Baeyens, J., Degreè, J. & Dewil, R., 2008. Principles and potential of the anaerobic digestion of waste-activated sludge. *Progress in Energy and Combustion Science*, 34, pp.755–781.
- 86 Verma, S., 2002. *Anaerobic Digestion of Biodegradable Organics in Municipal Solid Wastes* (MSc thesis). New York: Columbia University.
- 87 Ibid.
- 88 European Bioplastics, 2010. Fact Sheet: Anaerobic Digestion. *European Bioplastics*. Available at: <http://en.european-bioplastics.org/multimedia/> [Accessed 16 April 2013].
- 89 Tchobanoglous, G., Theisen, H. & Vigil, S.A., 1993.
- 90 McCurry, J., 2011. Japan streets ahead in global plastic recycling race. *The Guardian*, [online] 29 December 2011. Available at: <http://www.theguardian.com/environment/2011/dec/29/japan-leads-field-plastic-recycling>. [Accessed 16 April 2013].
- 91 Ibid.
- 92 Hoornweg, D. & Bhada-Tata, P., 2012.
- 93 Karak, T., Bhagat, R.M. & Bhattacharyya, P., 2012.
- 94 Hoornweg, D. & Bhada-Tata, P., 2012.
- 95 Regassa, N., Sundara, R.D. & Seboka, B.B., 2011.
- 96 UNSD. 2011.
- 97 Chua, K.H., Sahid, E.J.M. & Leong, Y.P., 2011. Sustainable Municipal Solid Waste Management and GHG Abatement in Malaysia. *Green and Energy Management*, 4, pp. 1–8.
- 98 Biffaward Programme on Sustainable Resource Use, 2003. *Thermal methods of municipal waste treatment*. Chester: C-Tech Innovation.
- 99 Hoornweg, D. & Bhada-Tata, P., 2012.
- 100 Biffaward Programme on Sustainable Resource Use. 2003.
- 101 Ibid.
- 102 Hoornweg, D. & Bhada-Tata, P., 2012.
- 103 Ibid.
- 104 Al-Khatib, I.A., Arafat, H.A., Basheer, T., Shawahneh, H., Salaha, A., Eid, J. & Ali, W., 2007.
- 105 Bai, R. & Sutanto, M., 2002. The practice and challenges of solid waste management in Singapore. *Waste Management*, 22, pp. 557–567.
- 106 Ibid.
- 107 Ibid.
- 108 Akinci, G., Guven, E.D. & Gok, G., 2012.
- 109 Henry, R.K., Yongsheng, Z. & Jun, D., 2006.
- 110 Ejaz, N. & Janjua, N.S., 2012.
- 111 Medina, M., 2011.
- 112 Ibid.
- 113 Regassa, N., Sundara, R.D. & Seboka, B.B., 2011.
- 114 Mahar, A., Malik, R.N., Qadir, A., Ahmed, T., Khan, Z. & Khan, M.A., 2007.
- 115 Da Costa, S.S., 2010. *The Brazilian National Solid Waste Policy*. Brazil: Ministry of the Environment. Available at: <http://www.reinnova.es/pdf/06.02%20Silvano%20Silverio%20Da%20Costa.pdf> [Accessed 5 July 2014].

- 116 National Commission of the Environment. 2014. Ecology and Environment: Chilean Environmental Law. *Embassy of Chile, Washington, DC*. Available at: <http://www.chile-usa.org/ecologye.htm> [Accessed 04 August 2014].
- 117 Wang, X.J., 1998. *Waste Reuse: Legislation and Enforcement in China*. Fifth International Conference on Environmental Compliance and Enforcement. 16–20 November 1998. California.
- 118 Zaki, T. & Khayal, A., 2010.
- 119 Rogero, A., 2010. *Assessment of the Solid Waste-management System of Bahir Dar town and the gaps identified for the development of an ISWM plan*. Forum for Environment.
- 120 Sheppard, D., 2010. *Pacific Regional Solid Waste-management Strategy 2010–2015*. 20th SPREP Meeting. 18 November 2009. Samoa.
- 121 CED (Centre for Environment and Development) 2011. Acts and Rules. *India Waste Management Portal*. Available at: http://www.indiawastemanagementportal.org/index.php?option=com_content&view=article&id=76&Itemid=162 [Accessed 8 August 2014].
- 122 Gilani-Lempges, S., 2013. *Biowaste Management*. Vienna Waste Management Conference. 7–11 October 2013. Vienna: ISWA. Available at: http://www.iswa2013.org/uploads/03_CompostingInIran_Shirzady_en_presentation_321_EN.pdf [Accessed 3 August 2014].
- 123 ELAW (Environmental Law Alliance Worldwide) 2012. Jamaica – National Solid Waste Managemnet Act (2002). *ELAW*. Available at: <http://www.elaw.org/node/2095> [Accessed 13 February 2013].
- 124 Yahaya, N., 2007. *Solid Waste Management*. Malaysia: UNDP. Available at: http://www.undp.org.my/uploads/c_Solid_Waste_Management_MHLG.pdf [Accessed 6 July 2014].
- 125 Kowlessar, P., 2012. *Solid Waste Management in Mauritius*. Mauritius: Ministry of Local Government and Outer Islands.
- 126 ELRI (Environmental Law Research Institute) 2012. *Compilation of Institutions & Waste Management Regulations in Nigeria*. Ikoyi: ELRI. Available at: http://www.docstoc.com/docs/95984601/Institutions_-Laws_-Regulations-on-Waste-Management-in-Nigeria [Accessed 13 February 2013].
- 127 Klean Industries. 2006. Waste management in desperate need in the Ukraine. *Klean Industries*, [online] 5 July 2006. Available at: http://www.kleanindustries.com/s/environmental_market_industry_news.asp?ReportID=143587 [Accessed 3 August 2014].
- 128 EPA, 2012. Legislation: Waste to Resources Policy. *EPA*, 16 October 2012. Available at: http://www.epa.sa.gov.au/environmental_info/waste/legislation/waste_to_resources_policy [Accessed 9 February 2013].
- 129 NREL (National Renewable Energy Laboratory). 1995. *Integrated Solid Waste Management in Germany*. Colorado: NREL.
- 130 Cesari, G., 2005. *Waste Management in Italy*. Rome: APAT.
- 131 Yamamoto, O., 2002. *Solid Waste Management in Japan, Status Quo*. Proceedings of International Symposium on Environmental Pollution Control and Waste Management. 7–10 January 2002. Tunis.
- 132 Johnson, A., 2007. *The Development of Waste Management Law*. Belmont: EMRC.
- 133 Huerta, O., Soliva, M., Martinez, F., Gallart, M. & Lopez, M., 2010. *Characterisation of municipal solid waste composts produced in Spain*. Proceedings of the 14th Ramiran International Conference. 12–15 September 2010. Lisbon.
- 134 DEFRA (Department for Environment, Food & Rural Affairs), 2014. Waste legislation and regulations. *GOV.UK*, 9 May 2014. Available at: <https://www.gov.uk/>

- waste-legislation-and-regulations#eu-waste-framework-directive [Accessed 3 August 2014].
- 135 Johnson, A., 2007.
 - 136 Kowlessar, P., 2012.
 - 137 CED. 2011.
 - 138 Chandrappa, R. & Das, D.B., 2012.
 - 139 Hoornweg, D. & Bhada-Tata, P., 2012.
 - 140 Ibid.
 - 141 Ibid.
 - 142 Ibid.
 - 143 Ibid.
 - 144 United Nations Economic and Social Council., 2009. *Africa Review Report on Waste Management*. Committee on Food Security and Sustainable Development Regional Implementation Meeting for CSD-18 (6th session). 27–30 October 2009. Addis Ababa.
 - 145 Ibid.
 - 146 Kehila, Y. & Gourine, L., 2010.
 - 147 Karak, T., Bhagat, R.M. & Bhattacharyya, P., 2012.
 - 148 Ibid.
 - 149 Zaki, T. & Khayal, A., 2010.
 - 150 Asase, M., Yanful, E.K., Mensah, M., Stanford, J. & Amponsah, S., 2009. Comparison of municipal solid waste management systems in Canada and Ghana: A case study of the cities of London, Ontario, and Kumasi, Ghana. *Waste Management*, 29, pp.2779–2786.
 - 151 Karak, T., Bhagat, R.M. & Bhattacharyya, P., 2012.
 - 152 Couth, R. & Trois, C., 2010. Carbon emissions reduction strategies in Africa from improved waste management: A review. *Waste Management*, 30, pp. 2336–2346.
 - 153 Karak, T., Bhagat, R.M. & Bhattacharyya, P., 2012.
 - 154 Mohamed, M.E.M.O.S., 2010. Country Report on The Solid Waste Management in Mauritania. *SWEEP-Net*. Available at: <http://www.sweep-net.org/ckfinder/userfiles/files/country-profiles/CountryreportMauritania-En-mai2011.pdf> [Accessed 26 March 2013].
 - 155 Mohee, R., 2002.
 - 156 Bouchareb, N., 2010. *Country Report on The Solid Waste Management in Morocco*. Available at: <http://www.sweep-net.org/ckfinder/userfiles/files/country-profiles/Countryreport-Morocco-En-mai2011.pdf> [Accessed 26 March 2013].
 - 157 Couth, R. & Trois, C., 2010.
 - 158 Ibid.
 - 159 Ayininuola, G.M., & Muibi, M.A., op. cit., pp. 1685.
 - 160 Trois, C. & Simelane, O.T., 2010. Implementing separate waste collection and mechanical biological waste treatment in South Africa: A comparison with Austria and England. *Waste Management*, 30, pp.1457–63.
 - 161 Kaseva, M.E. & Moirana, J.L., 2010. Problems of solid waste management on Mount Kilimanjaro: A challenge to tourism. *Waste Management & Research*, 28, pp. 695–704.
 - 162 Labidi, R., 2010. Country Report on the Solid Waste Management in Tunisia. Available at: <http://www.sweep-net.org/country/tunisia> [Accessed 26 March 2013].
 - 163 Couth, R. & Trois, C., op. cit., pp.2337.
 - 164 Manyanhai, I.O., Sigauke, E. & Munasirei, D., 2009. Analysis of domestic solid waste management system: A case of Sakubva high-density suburb in the city of Mutare,

- Manicaland Province, Zimbabwe. *Journal of Sustainable Development in Africa*, 11, pp.126–141.
- 165 Chandrappa, R. & Das, D.B., 2012.
- 166 Regassa, N., Sundara, R.D. & Seboka, B.B., 2011.
- 167 Muzenda, E., Belaid, M., Mollagee, M., Motampane, N. & Ntuli, F., 2011. *Reflecting on Waste Management Strategies for South Africa*. Proceedings of the World Congress on Engineering and Computer Science. 19–21 October 2011. San Francisco, USA.
- 168 Hoornweg, D. & Bhada-Tata, P., 2012.
- 169 Kehila, Y. & Gourine, L., 2010.
- 170 Zaki, T. & Khayal, A., 2010.
- 171 Hoornweg, D. & Bhada-Tata, P., 2012.
- 172 Labidi, R., 2010.
- 173 Mohamed, M.E.M.O.S., 2010.

CHAPTER 3

Solid Waste Collection and Transportation

Oomesh Gukhool

Introduction

Efficient waste management systems are essential in order to sustain economic and social development. However, most countries around the world are unable to maintain an adequate management system capable of handling the continuously growing mountain of waste that is generated. This is mainly due to inefficient collection systems. Waste collection and transportation represents the 'bottleneck' in integrated solid waste management (ISWM) operations and, for that matter, any other waste management strategies. Without collection, waste cannot be disposed of, treated or re-used. On the other hand, failing to collect waste leads to environmental and socio-economic repercussions.

Waste collection and transportation began in the early days of urbanisation. It has become a regular practice since then, and subsequently a key player in waste management. Nowadays, waste has to be collected on a regular basis (at least once per week). In most countries, the issue ranks among national priorities. The types of waste collected include domestic, commercial, bulk, construction, hazardous and industrial waste. Separation at source is very popular in developed countries; this consists of segregating plastic, paper, metal, glass, kitchen and green waste into respective bins. Authorities schedule specific collection days for such categories of waste.

Waste collection and transportation are regarded as the most costly activities in waste management. Local authorities earmark a significant portion (around 85 per cent) of their annual budget to waste collection, as opposed to other waste-management activities.¹ This is attributable to the various expenses involved in the collection process, such as:

- fuel consumption (based on travelling distance);
- salaries or wages of crew members;
- frequency of collection;
- waste generation; and
- the purchase and maintenance of collection vehicles.

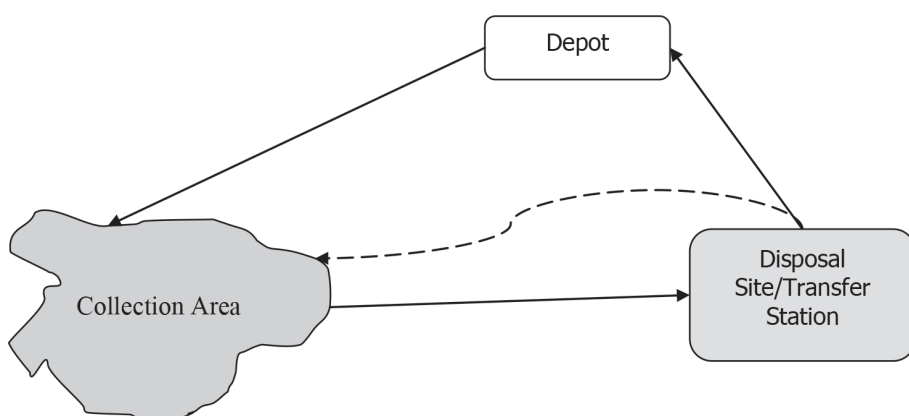
Beside the economic implications, waste collection and transportation have an adverse impact on the environment due to high CO₂ emissions from collection vehicles, noise pollution and unpleasant odours. In order to encourage waste treatment, it is essential to reduce collection costs. Similar trends have been observed in developing African countries.² This has led to major environmental and health issues in many of these countries.³ Therefore it is imperative to find adequate solutions in order to reduce not only costs, but health and environmental impacts too.

Solid Waste Collection

Regardless of technological enhancements or policy amendments, collecting and transporting waste remains a core pillar for the proper functioning of all solid waste activities in ISWM. In simple terms, waste collection is the core element linking waste generators with the waste management system.⁴ The process, as shown in Figure 3.1, includes four major steps, namely:

1. travelling from the depot to the collection area;
2. collecting waste from collection points;
3. transporting the waste to the nearest transfer station or treatment facility; and
4. travelling back to the collection area or the depot.

Figure 3.1: Waste collection and hauling process



The collection vehicle is likely to collect solid waste from all the residences (or other types of waste generators) in the area. Hence, the collection route for the vehicle constitutes a series of runs (distance between two residences) tethered to activities

such as: loading, idling, traffic stops, and on-vehicle compaction of wastes. The vehicle hauls the waste to the transfer station for disposal, after which it heads back to its designated area to continue or complete collection. Transfer stations are transitory disposal sites that avoid collection vehicles having to haul wastes over long distances for disposal at landfill sites. Recyclable waste is disposed of at specified treatment facilities designed to process these categories of material. Provided that it has performed all the collections in its designated area, the collection vehicle will return to the depot, or perhaps be sent to another collection area.

Likewise, cities in Africa have an organised solid waste collection system. However, collection coverage over the continent averages between 40 and 50 per cent: a situation in which the volume of waste collected exceeds the collection capacity.⁵ Pre-collection services are often provided by community groups in some areas, while municipalities carry out the major collections in most cities. To support local authorities in Africa, some private operators collect solid wastes on a fee basis. Transfer stations are not common in most African cities; instead, disposal points are located on the outskirts of the cities, thus facilitating the transfer of solid waste to the disposal grounds. To facilitate collection in densely populated African cities, a pre-collection system is used. Hence, small private operators collect solid waste in specific areas, thereby facilitating the collection process for local authorities.

Similarly, in Mauritius (the island is regarded as an African country), solid waste is collected by local authorities (municipalities and district councils) or by private-sector scavenging contractors. These collected waste is then disposed of at transfer stations across the island.⁶ Subsequently, the wastes are compacted and then taken for final disposal at the Mare Chicose landfill in the south of Mauritius. Quantities of wastes from the districts of Grand-Port and Savanne are disposed of directly at the landfill, without first transiting the transfer station. There are five transfer stations scattered around the island and serving six districts, excluding the Grand-Port and Savanne areas.⁷ The Mare Chicose landfill (in operation since 1997) has so far been able to accommodate 2,2 million tonnes of waste, and is likely to become a 'mega' landfill in the coming years.⁸

Waste collection and hauling is an intricate process, for the following reasons:

1. relentlessly soaring waste collection volumes;
2. source separation for treatment;
3. rising traffic levels and congestion;
4. increasing environmental impacts;
5. improved quality of life; and
6. better working conditions for collectors and operators.

The collection process absorbs about 85 per cent of the total cost of solid waste management systems in most countries around the world.⁹ Authorities in Mauritius therefore allocate a significant amount of their annual budget to the collection of wastes. Cost minimisation in waste collection is therefore one of the key priorities for local authorities and private companies worldwide.

The expense of the collection process arises from the following costs:¹⁰

1. labour;
2. vehicle maintenance;
3. fuel consumption;
4. spare parts;
5. equipment required for collecting waste;
6. insurance and road taxes;
7. vehicle value; and
8. collection frequency.

Such expenses compel local authorities to outsource the collection of waste to private companies. The time spent in collection and transportation is one of the factors decisively influencing overall costs.¹¹ The longer the time spent collecting or hauling wastes, the higher the costs will be. Collection vehicles consume more than 60 per cent of their daily fuel allowance during the collection of waste in an area,¹² and rising costs are often largely attributable to higher diesel consumption by poorly-maintained and aging collection vehicles. Numerous factors influence diesel consumption, namely:

1. hauling waste over long distances (transfer station located far from collection area);
2. travelling to and from collection areas;
3. long periods of unproductive engine idling while collecting waste;
4. stopping as a result of traffic congestion, stop signs or traffic lights;
5. considerable variations in run length (distance between households);
6. the amount of waste to be collected in the area; and
7. types of vehicles used, as well as their age and level of maintenance.

Reducing collection frequency, efficient distribution of collection crews and vehicles and route-planning are the most common strategies used nowadays to reduce waste collection costs.¹³ However, among all major solutions, minimising fuel consumption remains a key element in mitigating costs.

On one hand, waste collection and transportation has substantial economic impact, while on the other it entails significant impact on the environment. Studies carried out by Eisted and Larsen showed that collection vehicles emit between 9,3 and 32,3 kg CO₂-equivalent (kg CO₂-eq) per tonne of waste, subject to variations in collection method, vehicle type, vehicle bin capacity and travelling distance.¹⁴ Larsen et al. quantified the overall greenhouse gas (GHG) emission of collection vehicles for six different collection schemes, as shown in Table 3.1.¹⁵

Table 3.1: GHG emissions of collection vehicles¹⁶

Full service/kerbside collection	GHG emissions (kg CO ₂ -eq)
Residual waste, city centre	9,4–9,9
Residual waste, apartment blocks	5,0–5,4
Residual waste, single-family houses	10,2–11,5
Residual waste, rural areas	19,5–32,3
Paper waste, apartment blocks	6,8–11,2
Paper waste, single-family houses	12,7–21,1

Taxpayers and the population at large insist that collection vehicles collect their waste at least once per week. Not only is waste collection a subject of social concern, but irregular collection frequencies cause public discontent. Moreover, waste stored at household levels for longer than a certain period lead to hygienic degradation. Hence, authorities have the onerous duty of ensuring that regular collections are carried out for each resident. It has been observed that, due to poor collection services, people throughout the African continent tend to dispose of their waste in open dumps, thereby increasing environmental and health concerns.¹⁷

Waste Collection Components

A waste collection system is a patchwork of both technological and human exertions.¹⁸ The system regroups the following components:

- collection methods;
- vehicles;
- container systems;
- personnel; and
- route-planning.

The waste-collection system employed varies according to collection demands. The factors for establishing an appropriate collection system are:¹⁹

- waste composition;
- the existing collection system;
- the existing waste-generation and disposal system;
- willingness of the population to co-operate and pay;
- processing opportunities;
- marketing opportunities;
- distance to the drop-off centres;
- the system has to be simple and easy to understand (otherwise participation will be low);
- handling of the containers has to be easy;
- avoidance of unpleasant odours and vermin; and
- design (colours, arrangement of containers, etc.).

Collection Methods

Collection methods vary in accordance with whether sites are:

- Low-rise detached dwellings;
- Medium size apartments;
- High-rise apartments; or
- Commercial/industrial facilities.

The persistent rise in waste generation means that novel collection methods have to be implemented, such as collection of separated waste and other non-systematic collections.

Low-Rise Detached Dwellings

Waste-collectors tailor most of their activities around the collection of wastes in low-rise detached dwellings (also known as household collections). The common types of household collections include kerbside, alley, setout/setback, setout and backyard carry. Given the cost restraints and the social implications, authorities in most countries prioritise kerbside collection. Residents dispose of their wastes in special containers, which they leave at the kerbside on collection days.

Apartments

For most low-rise and medium-rise apartments, kerbside collection is common. Building maintenance staff is responsible for taking the bins out to the street for

kerbside collection - by either manual or mechanical means. In order to facilitate the collection of larger containers such as skips, special collection vehicles empty these bins mechanically. High-rise apartments use larger containers to store wastes. Depending on their size and type, the containers are either emptied mechanically, using collection vehicles equipped with unloading mechanisms, or using special vehicles that hook the loaded containers and haul them to an off-site location, where the contents are unloaded.

Commercial–Industrial Facilities

The collection of waste from Commercial/Industrial facilities creates traffic jams, due to the size of the collection vehicle and time taken for collecting. Therefore, to avoid traffic congestion during the day, solid wastes from commercial establishments are collected in the evening or in the early morning. The collection process necessitates three or four crew members, consisting of a driver and two or three crew members who load wastes from the kerbside into the collection vehicle.

Collection of Waste Separated at Source

In many countries, authorities encourage source-separation of solid wastes for recycling. People dispose of their waste into separate bins, depending on the type of waste. Collection types used for waste separated at source include: kerbside collection using conventional or specially-designed vehicles; incidental kerbside collection for charitable organisations; and delivery by homeowners to drop-off (civic amenity) and buy-back centres.

Non-Systematic Collection

Non-systematic collection is a method used to collect bulky wastes. These wastes are normally stored at household levels for long periods. Authorities occasionally organise special collection schemes to collect this type of waste. Occupiers put their bulky wastes on the kerbside in containers, or 'as is' on the announced collection date. Collection vehicles haul the collected bulky wastes to treatment plants or disposal sites.

Vehicles

Vehicles play a key role in the collection of solid wastes. Refuse trucks are still commonly used for the collection and transportation of waste. Throughout the years these vehicles have evolved, both technologically and mechanically. In order to reduce emissions, vehicles in the EU, for example, now need to conform to EURO standards. For instance, new trucks in Europe must now comply with the EURO V standard.¹⁹ Vehicle costs account for a large share of the overall collection expenses.

Collection vehicles guzzle significant amounts of fuel due to frequent stopings, idling, hauling over long distances and compaction. Greater diesel combustion yields fewer emissions, depending on the vehicle's engine size and exhaust system.²¹ A study by Knoch disclosed that collection costs are directly influenced by the vehicle's collection capacity.²² Today, there exists a large array of collection vehicles that comply with different collection traits and constraints. They are categorised as simple 'emptying method' vehicles and 'container' vehicles. Collection in African countries is often carried out using non-mechanical means, such as human-drawn or animal-drawn carts, as well as mechanical vehicles, such as open-back trucks, compactor trucks and trailers.²³

Vehicles for 'Simple Emptying' Method

Rear-Loading Vehicles

Rear-loading trucks are vehicles rigged with compactors, which enable a great quantity of wastes to be loaded into their container. Wastes are loaded, either mechanically or manually, at the rear of the vehicle. These vehicles are ideal the kerbside collection of household and commercial wastes, in both rural and urban areas. The rear-loading vehicles cope very well in narrow streets and restricted collection spaces in urban areas.²⁴ In Mauritius, rear-loading vehicles (Figure 3.2) are used in larger collection areas.

Figure 3.2: Rear-loading vehicles



Topper Bin Vehicles

Topper bin vehicles (Figure 3.3) are widely used in African countries, and in some regions of Mauritius. These vehicles are equipped with an open container, into which waste is loaded manually from the top. To maximise the container's capacity, crew members compact the stacked waste as far as possible using appropriate tools. Collecting waste using such vehicles is both time-consuming and costly.

Figure 3.3: Topper bin vehicle



Side-loading vehicles

The development of new vehicle types further contributes to the minimisation of waste collection and transportation costs. The side-loading truck sets the standards in terms of low-operating-cost collection vehicles. It enables collection with no additional personnel required. The driver operates a mechanical arm, attached to the side of the vehicle, to load wastes from bins at the kerbside. This type of vehicle is ideal for collection in suburban and rural areas, since the mechanical arm can extend up to three metres to seize the bin from the kerbside.

Front-Loading Vehicles

Waste from apartments and industries are stored in large bins. Front-loading vehicles equipped with a front-lifter raise and tip the bins into their containers. Like side-loading vehicles, front-loaders require no additional personnel to collect bins. The driver operates the lifter mechanically. The use of such vehicles is limited, due to their considerable size.

Multi-Chamber Vehicles

The advent of recyclable waste-collection activities has led to the use of multi-chamber vehicles. The vehicle's container comprises of horizontal or vertical chambers to accommodate the different types of waste. The multi-chamber vehicle reduces transportation costs, since it reduces the need for recurrent visits to disposal sites. One of the major drawbacks is the uneven stacking of wastes in the chambers, which can cause weight imbalances and difficulties in hauling.

Container Vehicles

Container vehicles are ideal for container-exchanging collection methods. The vehicles load and unload boxes, large containers or bins using different mechanisms. Vehicles of this type are categorised as:

- dump vehicles;
- hook-and-lift vehicles;
- roll-off vehicles; and
- lift-off vehicles.

In Mauritius, these vehicles hook- up waste containers at transfer stations and transport them to the landfill. These container vehicles have a bigger engine capacities, which enables them to haul greater amounts of waste.

Container System

Containers, commonly known as bins, are vital for the storing of solid wastes prior to collection. Containers are used in households, commercial centres, industries, civic amenity centres and many other places. Collectors capitalise on different container sizes and designs to render the collection process more efficient. Waste- bins enhance hygiene as well as improving workers' safety. Their sizes vary from 120 to 1 100 litres in most countries.²⁵ In Mauritius, the capacity of most containers ranges from approximately 40 to 1 100 litres. Plastic containers (less than 360 litres) are used at household and commercial levels. Most of these containers are equipped with a pair of wheels. Wheels (known as 'Wheelie Bins') and, they are ideal for kerbside collection. Larger-capacity bins (1 100 litres) are four-wheeled metal containers suitable for apartments, industries, and commercial areas. Containers are therefore key elements in determining the most appropriate type of collection vehicle for an area.

Personnel

Personnel are another major constituent of any collection system. The personnel assigned to a vehicle consist of a driver, and from two to eight other crew members.

Crew members collect waste containers and load them into the vehicle. The crew size of a vehicle influences collection costs. Furthermore, increasing crew member numbers necessitates additional safety measures and equipment. For a typical kerbside collection system, two crew members will be sufficient to service an area. In Mauritius, crew sizes generally vary between five and nine, due to the complex kerbside collection system. In some cases, crew members are compelled to remove wastes stored in fixed concrete bin boxes. The Mauritian Government authorised the construction of concrete bin boxes in the early 1980s, and they are still utilised by some residents. Nevertheless, determining the crew size needed for an area is still a contentious issue.

Collection Route Planning

Effective route-planning mitigates collection costs and time, over and above environmental impacts. Route-planning is an intricate process whereby planners need to take into consideration the vehicle's collection path in a realm, travelling to and from the area, and the hauling of wastes. Hence, collection route-planning necessitates a holistic approach that embraces all the key elements of the process. These core components are:

- collection method;
- categories of wastes to be collected;
- waste volume for the area;
- container system presently used in the area;
- vehicle type and capacity;
- average run-lengths for ealmarea;
- hauling distances;
- crew members;
- collection time;
- disposal time (queueing time at disposal sites);
- street layout of the collection area; and
- road constraints no -through-roads, stop and no-entry signs, street and alley width).

In recent years, researchers have been have focusing on various ways to optimise collection routes. The aim is to reduce the vehicle's fuel consumption through better route-planning, and eventually to alleviate wasted osts, time, and environmental imacts.²⁶

Waste Collection Solutions

Solid waste collection has long been a serious issue for ISWM.²⁷ Engineers, researchers and authorities studied and formulated numerous solutions, including optimisation models and tools, to counteract the growing difficulties of collection. For instance, Eisenstein and Iyer studied the scheduling of collection vehicles in Chicago and introduced a flexible routing scheme pertaining to visit frequencies at disposal sites.²⁸ However, as reported by Dogan and Suleyman, vehicle diesel expenditure is one of the driving factors of high collection cost.²⁹ Optimising collection routes is therefore an adequate solution to alleviate diesel consumption and overall collection expenses. Today, researchers focus mainly on achieving best-optimised route using different algorithms and mathematical solutions. Authorities and private companies support such endeavours, in view of the anticipated solutions to reduce costs and emissions.

Route Optimisation

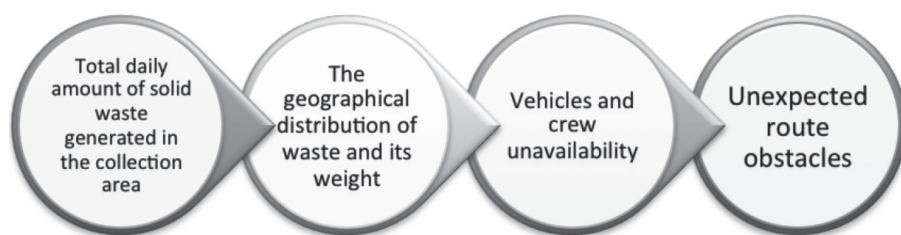
Road networks are of prime importance in optimising waste collection and transportation. Over the years, researchers have been working on shortest-path algorithms for Travelling Salesman Problems (TSP) and Vehicle Routing Problems (VRP). Most of the techniques developed for waste collection and hauling optimisation accord with the TSP or VRP concepts, which is to find the shortest path in an area. However, recent studies have shown that the shortest route for a collection area does not necessarily lead to a decline in costs and emissions.³⁰ In fact, cost and emission reductions are more easily achieved when routes are optimised using a multi-objective approach.³¹ Multi-objective techniques are broadly utilised in problems where one single objective fails. Multi-objective optimisation problem (MOP) is the process of optimising concurrently two or more inconsistent objectives with respect to certain limitations (vector functions). Vector functions are mathematical interpretations of conflicting criteria. Hence, MOP provides appropriate solutions and satisfies all the objective functions. Multi-objective optimisation is a concept commonly associated with transport engineering. Finding the best transportation routes depends exclusively on the fulfilment of all defined objectives. Recently, the concept of 'round optimisation' has been introduced, whereby collection routes are optimised in its integrity.³² This concept is based on the optimisation of existing rounds or by designing new rounds, using adequate types of vehicles and crewmembers (depending on collection area sizes, and types of wastes to be collected). It is hoped that such an approach will reduce costs by 15 per cent, and hence mitigate mileage and reduce carbon footprints.³³

Waste-collection and hauling integrates numerous parameters delineating the process. Each parameter corroborates a specific criterion. Gathering all the parameters together defines the multi-objective criteria for the collection and hauling of wastes. Therefore, altering these elements impacts on collection and hauling route patterns, thereby resulting in variations for diesel consumption and CO₂ emissions. Unlike conventional transportation planning, waste-collection inherits a more elaborate multi-objective approach. It has broader vector functions, due to the complexity of the process. The development of an effective route-optimisation technique for waste collection relies on profoundly established multi-objective criteria. A comprehensive waste-collection model is an appropriate means to bring together all the elements of the process, in order to determine the multi-objective approach.

Waste Collection Modelling

For decades, researchers modelled solid waste collection using a variety of methods.³⁴ Most of these conventional models address waste collection elements only partially. Waste-collection and hauling encompass constantly changing parameter values. It is a dynamic and complex process and is continually changing. The degree of complexity varies significantly depending on a series of variables. Variability is thus a key factor in every collection system. Corrective measures are essential to mitigate its negative effects, such as rising costs due to the need for more trips, more crewmembers, overtime and vehicles. The main variability sources are shown in Figure 3.4.

Figure 3.4: Main variability sources



Regardless of the various methodologies applied, solid waste collection and transportation models share the same key elements:

- collection frequency depends on the waste-generation rate and its maximum allowed exposure time;

- each collection team has an assigned route, where they must collect all the waste in one shift;
- the number of routes being collected at the same time depends on the availability of vehicles; and
- a collection area is divided into routes, taking into consideration vehicle capacity, variability in waste-generation rates and collection frequency.

Studies undertaken by Truitt et al. revealed further parameters relevant for the establishment of an adequate waste collection model, such as transfer station location and collection frequency.³⁵ On the other hand, Tchobanoglous et al. depicted additional elements, such as available time per route, required vehicle capacity and the number of vehicles and routes required, which enhance waste collection models.³⁶

Route Time Model

One of the major breakthroughs in waste-collection modelling was the formulation of the route time (RT) model by Everett and Shahi.³⁷ They worked out a route/time estimation model for yard waste collection. The model estimates RT for a collection route as a summation of the total time spent travelling (i.e. travelling between runs), stopping (due to traffic constraints) and collecting wastes in an area (Figure 3.5). Modelling the collection process through time has long been a subject of concern to many researchers. Lately, studies have proven the effectiveness of time impacts in terms of cost and emission reductions.³⁸ The various simulations carried out invoke the potentials of the RT model. Everett and Shahi used the model to evaluate the effects of set-out rates (SOR) on RT and yard- waste -collection frequencies.³⁹ The SOR is the rate at which occupiers set out their bins on collection days. For instance, a household might set out two bins for a particular collection day, and one bin on another day. Gukhool et al. expanded their concept by taking new factors into considerations, such as vehicle and labour requirements.⁴⁰

Figure 3.5: Route time model



Everett and Shahi used simulation modelling to prove that route time is a function of SOR, and that the frequency and distribution of set-outs on kerbsides have a direct

impact on total travelling time.⁴¹ Though RT modelling is an intriguing concept, it harnesses an empirical travel-time equation. On the other hand, the RT model has been criticised for its deficiencies in terms of some dynamic parameters. Based on these constraints, Wilson and Baetz presented a derived probability model to estimate vehicle and labour requirements for municipal solid waste collection systems.⁴² They used a probabilistic approach, rather than the conventional simulation model for route time. According to Wilson and Baetz, the major problem with simulation models is that they are not appropriate for determining optimal conditions instantly, and require many runs with one-at-a-time parameter variation.⁴³ Wilson and Baetz extended their approach through the application of different conditions.⁴⁴ However, because this model is restricted to pre-defined parameters, it is unable to accommodate for dynamic elements. Despite the limitations of the RT model, it remains the bedrock for the multi-objective approach for optimisation. Profound amendments to the current RT model will enhance its potentials to reproduce the overall characteristics of the collection process.

Optimisation Methods

Collection and transportation route-optimisation using a multi-objective approach is complex. The Geographical Information System (GIS) is one of the major platforms used to solve such complex optimisation problems. It is a unique tool, which is well suited to capture, store, analyse, and manage spatially-referenced data, such as points, lines, and polygons (vector data model), or continuous fields (raster data model). Used as a spatial database, GIS assists the modelling of waste collection by handling a special form of data that facilitates its interpretation. Chang et al. studied the ability of GIS, used with a multi-objective programming model for vehicle routing and scheduling, to analyse the optimal path between a given origin and destination in a waste-collection network.⁴⁵ In this context, optimisation seeks to minimise total collection distance, cost and time.

However, one of the major criticisms of using GIS for waste collection purposes is its use of restricted optimisation engines. In other words, GIS tools have a constrained vector function, which means that optimal routes are obtained at using only a few major objectives. As a result, researchers are focusing on novel techniques for waste-collection and hauling. Evolutionary algorithms (EA), which is a component of evolutionary computation and a 'generic population-based metaheuristic optimisation' algorithm, is one of these. The techniques that EA uses for waste-collection optimisation include:

- fuzzy logic (with the application of EA);
- generic algorithm;

- tabu search; and
- ant colony optimisation.

Conclusion

This chapter explains processes in waste collection and transportation. It highlights the problems associated with the process and its complex cost implications. Researchers have acknowledged the importance of route-optimisation in order to mitigate economic, social and environmental impacts. However, recent studies have revealed that tethering a multi-objective approach with route-optimisation would render a far more efficient solution for the collection process. Optimising the waste-collection process is complex, and requires an adequate optimisation technique that is capable of handling multiple criteria in order to determine the best routes with minimal cost impact.

Notes and References

- 1 Scharff, C. & Vogel, G., 1994. A Comparison of Collection Systems in European Cities. *Journal of Waste Management & Research*, 2(5), pp.387–404.
- 2 Chukwubueze, O.A., 2011. The political economy of refuse collection and disposal in Nigerian urban centres. *Journal of Sustainable Development in Africa*, 13(11), pp.214–24.
- 3 Bartone, C., 2000. *Strategies for Improving Municipal Solid Waste Management: Lessons from World Bank Lending and CWG Activities*. Workshop on Planning for Sustainable and Integrated Solid Waste. 18–21 September. Washington: Urban Management Division, World Bank.
- 4 White, P.R., Franke, M. & Hindle, P., 2001. *Integrated solid waste management – A lifecycle inventory*, *Black Academic & Professional* (2nd ed.). Kent: Blackwell Science.
- 5 UNEP, 2005. *Solid Waste Management (Volume II: Regional Overviews and Information Sources)*. California: CalRecovery.
- 6 Ministry of Local Government., 2006. *Technical note on current status of solid waste management and recycling*. Republic of Mauritius: MoLG.
- 7 Ibid.
- 8 Ibid.
- 9 Scharff, C. & Vogel, G., 1994.
- 10 Dogan, K. & Suleyman, S., 2009. Report: Cost and financing of municipal solid waste collection services in Istanbul. *Journal of Waste Management & Research*, 21, pp.480–5.
- 11 Bhat, V.N., 1996. A model for the optimal allocation of trucks for solid waste management. *Journal of Waste Management & Research*, 14, pp.87–96.
- 12 Nguyen, T.T.T. & Wilson, B.G., 2010. Fuel consumption estimation for kerbside municipal solid waste (MSW) collection activities. *Journal of Waste Management & Research*, 28(4), pp.289–97.

- 13 Miles, S.B. & Ho, C.L., 1999. Applications and issues of GIS as tool for civil engineering. *Journal of Computing in Civil Engineering*, 13(3), pp.144–52.
- 14 Eisted, R., Larsen, A.W. & Christensen, T.H., 2010. Collection, transfer and transport of waste: accounting of greenhouse gasses and global warming contribution. *Journal of Waste Management & Research*, 27, pp.738–45.
- 15 Larsen, A.W., Vrgoc M., Lieberknecht, P. & Christensen, T.H., 2009. Diesel consumption in waste collection and transport and its environmental significance. *Journal of Waste Management & Research*, 27, pp.652–9.
- 16 Ibid.
- 17 Abul, S., 2010. Environmental and health impact of solid waste disposal at Mangwaneni dumpsite in Manzini: Swaziland. *Journal of Sustainable Development in Africa*, 12(7), pp.64–78.
- 18 Bilitewski, B., Hardtle, G. & Marek, K., 1997. *Waste Management*. Berlin: Springer.
- 19 Nguyen, T.T. & Wilson, B.G., 2010.
- 20 DieselNet, 2012. Emission Standards: Europe: Heavy-Duty Truck and Bus Engines. *Diesel-Net*. Available at: www.dieselnet.com/standards/eu/hd.php [Accessed 12 April 2013].
- 21 Eisted, R., Larsen, A.W. & Christensen, T.H., 2010.
- 22 Knoch, J., 1986. Collection and transport of solid waste in the Federal Republic of Germany. *Journal of Waste Management & Research*, 4, pp.137–45.
- 23 UNEP, 2005.
- 24 Pieber, M., 2004. Waste collection from urban households: In Europe and Australia. *Waste Management World*, July – August, pp.111–23.
- 25 Bach, H., 2003. Quantitative Abfallanalytik. *Skriptenreihe des Institutes für Technologie und Warenwirtschaftslehre der Wirtschaftsuniversität*, p.21.
- 26 Gukhool, O., Bokhoree, C., Mohee, R. & Jamnejad, G., 2010. Techniques for the Reduction of CO₂ Emissions for Solid Waste Collection Vehicles. *International Journal of Climate Change: Impacts and Responses*, 2(2), pp.109–16.
- 27 Nuorti, T., Kytöjoki, J., Niska, H. & Braysy, O., 2006. Improved route planning and scheduling of waste collection and transportation. *Expert Systems with Applications*, 30(2), pp.223–32.
- 28 Eisenstein, D.D. & Iyer, A.V., 1997. Garbage collection in Chicago: A dynamic scheduling model. *Management Science*, 43, pp.922–33.
- 29 UNEP, 2005.
- 30 Sonesson, U., 2000. Modelling of waste collection: A general approach to calculate fuel consumption and time. *Journal of Waste Management & Research*, 18, pp.115–23.
- 31 Apaydin, O. & Gonullu, M.T., 2008. Emission control with route optimization in solid waste collection process: A case study. *Sadhana*, 33(2), pp.71–82.
- 32 Webaspx, 2012. WMDesign Optimisation Software. *Webaspx*. Available at: <http://www.webaspx.com/products-services/waste-collection/wmdesign/> [Accessed 8 March 2013].
- 33 Ibid.
- 34 Wang, F.S., Richardson, A.J. & Roddick, F.A., 1997. SWIM: A computer model for solid waste integrated management: Computers. *Environment and Urban System*, 20(4/5), pp.233–46.
- 35 Truitt, M.M., Liebman, J.C. & Kruse, C.W., 1970. *Mathematical modelling of solid waste collection policies*. Washington: US Department of Health, Education and Welfare.

- 36 Tchobanoglous, G., Theisen, H., & Vigil, S., 1993. *Integrated Solid Waste Management: Engineering Principles and Management Issues*. New York: McGraw Hill.
- 37 Everett, J.W. & Shahi, S., 1996. Curbside collection of yard waste: I. Estimating route time. *Journal of Environment Engineering*, 122(8852), pp.107–14.
- 38 Eisenstein, D.D. & Iyer, A.V., 1997.
- 39 Tchobanoglous, G., Theisen, H. & Vigil, S., 1993.
- 40 Gukhool, O. & Bokhoree, C., 2010. Optimising Route Time for Solid Waste Collection Through Variations in Vehicle Capacity. *World Academy of Science, Engineering and Technology*, 68, pp.115–8.
- 41 Tchobanoglous, G., Theisen, H. & Vigil, S., 1993.
- 42 Wilson, B.G. & Baetz, B.W., 2001. Modelling municipal solid waste collection systems using derived probability distributions: I. Model Development. *Journal of Environment Engineering*, 127(22227), pp.1031–8.
- 43 Ibid.
- 44 Ibid.
- 45 Chang, N., Lu, H.Y. & Wei, Y.L., 1997. GIS technology for vehicle routing and scheduling in solid waste collection systems. *Journal of Environmental Engineering*, 123(9), pp.901–10.

CHAPTER 4

Treatment of Solid Waste: Principles, Key Technologies and Selected Case Studies from Africa

Ackmez Mudhoo, Geeta Devi Somaroo and Romeela Mohee

Introduction

Efficient waste management and disposal are pressing issues facing African countries today. Rapid population growth, urbanisation and industrial growth have led to severe waste-management problems in many countries. The large quantities of waste generated necessitate a controlled system of collection, transportation and disposal. The process requires knowledge of the composition of the waste, and how it needs to be collected and disposed of in a sustainable way. In terms of the stabilisation and recycling of waste, biological treatment as well as energy recovery and employment opportunities arising from solid waste management (SWM) have equally large potentials in Africa. Successful waste management requires the participation of citizens, local government and private entrepreneurs. For a healthy environment, both municipal and industrial waste should be managed according to the Integrated Solid Waste Management (ISWM) hierarchy: prevention, minimisation, recovery, incineration and landfilling. Among the methods by which waste could be managed are incineration, recycling, anaerobic digestion (AD), landfilling and composting.

In sub-Saharan Africa in particular, the combined influence of poverty, population growth and rapid urbanisation has worsened the situation.¹ The whole issue may be better understood when the amount of consideration given by the United Nations (UN) Millennium Declaration of September 2000 is gauged. Part of the Millennium Development Goals (MDGs) involves waste or resource-efficiency implications. This is aimed at reversing the loss of environmental resources and eradicating extreme poverty and hunger. Due to an increase in urban population, with a growth rate exceeding four per cent, the current system for the collection and transport of waste in developing countries is inadequate.² Municipal Solid Waste (MSW) is generally composed of non-hazardous industrial waste fractions, as well as commercial and domestic waste. It consists of organic wastes, street-sweepings and other yard waste, as well as hospital and other institutional refuse. This, in turn, includes organic wastes, plastics and papers, and construction waste. However, a report by Schübeler³

revealed that contaminated medical and hazardous industrial waste formed part of the waste stream in certain nations. Management of MSW in developing countries is often characterised by inadequate service coverage, operational inefficiency of services, limited utilisation of recycling activities and insufficient management of non-industrial hazardous waste and landfill management.⁴ The problems in developing countries differ from those in fully industrialised countries, as can be seen when comparing the composition of their waste. Various studies note stark differences between the two, with waste density and moisture content typically two to three times greater in developing than in developed countries. It is interesting also to note that large quantities of organic waste, dirt and dust, with correspondingly smaller particle size, are seen in poorer areas than in industrialised ones.^{5,6}

In principle, sustainable SWM could aim to continually improve the environment in which it is practised, provide direct health benefits, support economic productivity and provide safe and secure employment.⁷ In response to the waste challenge, many African countries have embarked on ambitious environmental reforms, recording fair improvements in best practice and sustainable management of their municipal solid waste streams. This chapter presents a number of case studies, illustrating the successes and limitations in the practice of SWM by African countries. SWM routes discussed in this chapter are AD, composting, incineration, landfilling and recycling. This paradigm shift in SWM, however, involves unregulated public participation in waste collection and processing for final disposal.

AD Technology

AD has proven to be a sustainable approach for the treatment of organic waste. Managing solid organic waste sustainably, while at the same time providing for the recovery of useful by-products and renewable biofuels, offers significant environmental benefits.⁸ With its widespread application around the world, mainly in developing and under-developed countries, this technology could alleviate the problem of energy insecurity and limit greenhouse gas emissions, thereby contributing to the fight against climate change. As mentioned by Khanal⁹ in his *View of integrating anaerobic digestion in developing nations*, there is a need to fulfil the following:

- improvement in health and sanitation through pollution control;
- generation of renewable energy for household activities; and
- supply of digested materials for use as bio-fertiliser for agriculture.

With an understanding of the AD process came more sophisticated equipment and operational techniques, together with improved benefits. European countries have explored the AD market, due to constraints such as higher energy prices and the increasingly stringent environmental regulations often applicable to their situations.¹⁰ Various AD technologies have been used to treat a range of waste streams from municipal to agricultural and industrial waste is an indication of its applicability.

Process of AD

AD can be used for the treatment of biodegradable waste, for production of energy in the form of biogas. The digestate produced can be transformed into a soil amendment. The AD process involves several stages:

- pre-treatment;
- digestion;
- gas upgrading; and
- digestate treatment.

The pre-treatment phase of the AD process is determined by the specific characteristics of the different components and substrates making up the entire feedstock. The process of digestion involves the degradation and stabilisation of organic materials under anaerobic conditions through the action of micro-organisms, leading to the formation of biogas, which is a mixture of carbon dioxide, methane, and digestate.^{11,12} The science underlying AD can be very complex, by reason of the extensive sets of biochemical reactions which operate and compete to determine the individual sub-process kinetics and overall macroscopic process dynamics. AD is normally broken down into the three main stages of hydrolysis, acidogenesis/acetogenesis, and methanogenesis. The first phase, hydrolysis, is the period in which insoluble, complex organic components such as proteins, fats and carbohydrates are broken down into sugars and amino acids. However, it has been observed that, in waste consisting of a high proportion of organic matter, the hydrolytic activity is of significant importance, and in some cases can be regarded as the rate-limiting step.¹³ The next phase is the conversion of products from the first step into organic acids, carbon dioxide and hydrogen, using a group of bacteria known as acetogenic bacteria. Finally, a third group of bacteria, described as methanogens, converts the hydrogen, carbon dioxide and acetate into methane.¹⁴

Africa and Anaerobic Biotechnology

On average, 70 per cent of African countries depend on imported energy resources, which support the need to harness available energy, either from waste or from

biomass.¹⁵ In sub-Saharan Africa, it has been estimated that more than 500 million people do not have electricity, and rely mostly on solid forms of biomass (such as firewood and agricultural residue) to meet their basic energy needs. Renewable energy, such as AD, could solve the energy problem in developing countries, and can be regarded as a technology that will ease their energy and environmental problems. Omer and Fadalla¹⁶ noted that a number of small-scale biogas plants are located around the continent, in places such as Burundi, the Ivory Coast and Tanzania – albeit with only a few being operational. Due to poor reliability, weak performance and poor technical quality, biogas production plants have a short life-span. The comprehensive and marketable development of large-scale AD technology in Africa may still be considered to be in its infancy, but it has a great deal of potential. From a survey of the literature, it has been observed that there is a need to introduce more efficient bioreactors to improve both biogas yields and foster the development of large-scale anaerobic technology in countries such as Botswana, Burkina Faso, Cameroon, Ethiopia, Malawi, Namibia and Sudan.

Tanzania

A project named TAKA (waste) Gas is being implemented in Tanzania, which deals with the growing problem of solid waste, while at the same time producing biogas for electricity production. Since the material is composed primarily of organics, this project will dispose of a large amount of waste, at the same time protecting the environment from the degradation caused by wood fuel extraction. This project is expected to generate 5,18 MWh/d.¹⁷

Kenya

At present there is no working biogas plant in Kenya that treats organic solid waste; but for the past five years a company has been trying to implement one. One of the suggested projects consists of a digester with a capacity of 14m³, which will treat organic solid waste from Mtwapa for the generation of electricity largely in order to run a water pump.

Ghana

The few biogas plants that were installed in the country have all failed, according to Müller.¹⁸

Composting Experiences in Africa

Composting, according to Hoornweg et al.,¹⁹ is a cornerstone of sustainable development often neglected in integrated municipal SWM programmes, and over 50 per cent of the MSW in developing countries could be readily composted, thereby diverting organic materials from open dump sites. Composting can be an effective and sustainable means to improve on existing recovery rates of recyclable organic and inorganic waste. However, in developing countries, large and centralised composting plants are often not economical, due to high operational, maintenance and transportation costs and a lack of funding to administer such services. It has, however, been demonstrated that smaller composting plants are practical alternatives, since they require less technological and financial capacity, even though they involve more human labour.²⁰ Despite these efforts, many large and small composting projects have failed, because not enough attention was given to the marketing and quality of the product. Of 37 composting Clean development mechanism (CDM) projects, only 12 are based on MSW, and none of them has issued an emission reduction certificate.²¹

Like other developing countries, African nations are confronted with extensive SWM issues, due to their growing population and increasing resource consumption, while their existing infrastructures and legislations remain the same. This is often the reason behind the failure to keep up with demand.²²

Tanzania

Mbuligwe et al.²³ conducted a composting research and pilot-scale composting demonstration project in Tanzania to test the applicability of composting as one of the waste-minimisation and resource recovery techniques for household wastes. This study reveals that organic wastes make up around 78 per cent of the total MSW, with composting achieving a waste volume reduction of 49 to 70 per cent. In this same project, a composting plant (KIWODET) was set up, as positive results were achieved with composting. Oberlin and Szántó²⁴ analysed the success and failure of this project, and their results showed that, despite the waste being readily available and of good composting quality, not all of the waste stream qualified as feedstock for the composting process. It should also be noted that negative consumer attitudes to compost made of residential waste hindered the commercial exploitation of the compost. Regardless of these issues, KIWODET managed to put in place a composting plant in Tanzania that contributed to additional waste collection and sorting activities, as well as to the development of integrated informal waste collection activities.

Ghana

A project was launched in Kumasi, Ghana, which involved the co-composting of faecal sludge and the organic fraction of solid wastes. This composting plant was

designed as a small-scale pilot facility. Due to lack of funds it is not currently operational; however results, produced over its seven operating years indicate that similar projects can help contribute to safe waste-management, provided that there is proper funding.²⁵ In 2010, a CDM composting plant project was signed with Zoomlion, the leading waste-management company in Ghana. This project will process around 300 tonnes of waste daily, increasing in 2013 to 600 tonnes,²⁶ and it is expected to reduce greenhouse gases from open dump sites in Ghana.

Nigeria

Taiwo²⁷ has mentioned that, in Nigeria, composting of MSW has failed in various regions of the country, due to a lack of funds and inefficient management of the site. This has led to various environmental problems, such as the release of methane, odour emissions and heavy-metals accumulation in the final product.

Incineration Processes

In an integrated waste-management approach, thermal treatment or incineration is often the next-to-last option after waste prevention, re-use, recycling and composting have been considered. Incineration is essentially described as the combustion of as-received MSW under controlled conditions and in an enclosed engineered structure, which may or may not include energy recovery systems. Incineration plants usually have combustion temperatures in excess of 750 or 800° Celsius. The feed is eventually converted into carbon dioxide and water as the main products. However, this method should not be exclusively considered as a disposal option, since there is still a fair quantity of ash that needs to be taken care of as safely as possible, and which is often disposed of in landfills, as well as some gas emissions that escape into the strata of the atmosphere. Rand et al.²⁸ suggest that thermal treatment of waste should be considered more in terms of waste-reduction potential, since around 80 to 90 per cent of the volume of the waste is reduced during this process. Specific technical expertise and related general repair and maintenance technology are often absent in developing country scenarios. According to United Nations Environmental Programme (UNEP),²⁹ incinerators have been shut down in many cities around the world, including Buenos Aires, Mexico City, Sao Paulo and New Delhi, owing to their high repair and maintenance cost and related environmental problems.

Types of Thermal Treatment

Thermochemical treatment processes form an essential component of suitably integrated municipal SWM. Incineration allows for efficient treatment of different types of waste (both hazardous and non-hazardous and in different states of matter, i.e.

liquid, semi-solid, sludge or solid), which includes unsorted residual wastes that cannot be further recycled from an environmental and economic point of view. The two most widely-used types of incineration plant are mass-burn and modular; however, more emphasis is being placed on nowadays on energy-recovery systems that include gasification and pyrolysis. Before being processed as a fuel, MSW requires pre-treatment processes, which normally consist of shredding the material down to a homogeneous mixture and then optionally mixing it with other fuels to initiate the incineration process. An important aspect to be considered in MSW incineration is the moisture content of the waste. Frey et al.³⁰ mentioned a value of 8,3 MJ/Kg, with a moisture content of 29 per cent in Europe; while Ruth³¹ cites a value of 10,4 MJ/Kg with 25 per cent moisture for the US. In developing countries, the moisture content varies from 39,8 to 62,2 per cent, owing to the higher percentage of organic matter contained in the waste.³²

Nigeria

Neither incineration nor any other thermal treatment is practiced in Nigeria, with the exception of hospitals, where medical wastes are incinerated on a small-scale basis. As mentioned earlier, this type of treatment requires expensive infrastructure and maintenance costs, as well as strict control of toxic fumes and disposal of toxic residues in a sanitary landfill. In 1979, three incinerators were built at a cost of US\$10 million, but could only be operated normally, with addition of fuel in order to maintain combustion mainly due to the high moisture content of the waste.³³ A low calorific value, combined with low combustible components of solid waste, makes the incineration process uneconomical in Nigeria.³⁴

Ethiopia

In a study done by Regassa et al.,³⁵ a survey was conducted to find out whether incineration was practiced or not, and it was found that around 24,2 per cent of the survey respondents responded positively to incineration being practiced occasionally, at secured places.

Tanzania

Recently, a waste-to-energy incinerator unit has been installed and commissioned in Tanzania, with the support of some foreign expertise and assistance. Such a joint venture, with firms from industrialised countries, makes this type of initiative more feasible, since it provides developing nations with the capital and technology required. Even with the initial high cost of the incinerator being wholly subsidised, the project failed. The costs of operating and maintaining the incinerator properly were

still too high for the developing country to sustain. Among the reasons for the failure of this project was the cost of strict environmental control.³⁶

Land Filling Practice

Developing countries in Africa are faced with a growing concern about the insufficiencies of SWM practices. The reason for this is a waste strategy that is not well accepted and understood, when compared to developed countries. These developing countries have generally continued to use unsophisticated methods, such as open dumps.³⁷ As mentioned by Tinmaz and Demir³⁸ and Al-Khatib et al.,³⁹ there is a lack of organisation and planning in waste management, which is largely due to insufficient information about regulations and financial restrictions in many developing countries. Workable legislation, regulations and action plans in developed countries maintain a safe waste-management strategy. For a number of reasons, primarily resulting from poverty, a lack of education and opportunity, and to some extent the adherence to very old customs, the difficulty of upgrading policies and practices for the disposal of MSW is far more complicated than in developed nations.

Developing countries have adopted numerous methods for the treatment and disposal of their MSW, including recycling methods, composting and sanitary land filling.⁴⁰ In most African countries, open dumps are the preferred method of disposing of solid waste, as an alternative to landfills. Open dumps are simple open sites with no engineered measures, no leachate management and no consideration of landfill-gas management. Even though most developing countries regard this method as being unsafe and unhygienic, they have no choice other than to continue with it. This could be due to a lack of funds for managing properly-engineered landfills.⁴¹ It has been observed that sanitary engineered landfills are found mostly in South Africa, Botswana and Zimbabwe, while most developing countries in Africa are still reliant on the open-dumping method. Even though some countries have adopted the landfill method, these operate as dump sites due to a lack of the financial resources needed to maintain them.

Kenya

Kenya has seen rapid growth in MSW generation, while the collection and safe disposal of waste is on the decline. Current waste disposal in Kenya is in open dumps, which, according to Henry et al.,⁴² lack proper environmental pollution control and monitoring. In 2003, the Minister of Local Government forced the relocation of the Dandora Dumping Site, since it had become an eyesore, prone to the development and proliferation of diseases and there was the possibility of it causing aircraft accidents due to large flocks of birds at the dumping site, which is in the proximity of the

airport. The dumping sites in Kenya do not meet the basic requirement of protecting ground water pollution by leachate, as they lack liners. In Lake Victoria, the illegal disposal of solid and liquid waste in rivers has resulted in the accelerated growth of water-hyacinth.⁴³

Nigeria

In a study done by Agunwamba,⁴⁴ Nigeria was found to have only three landfills. It is observed that the capital city of Nigeria does not have any sanitary landfill, and all waste from formal collection in the various districts is transported to a single site at Mpape. The largest dump site in Africa, the Olusosun landfill, is found in Nigeria. It has an area of 42 hectares, and receives up to 2 400 metric tons of waste each day, including hazardous waste (chiefly infectious medical waste and toxic industrial solid waste). This is equal to around 40 per cent of the total waste generated by the city of Lagos.⁴⁵ Apart from the Olusosun landfill, two other such landfills, Abule-Egba and Solus, are also found in Nigeria.⁴⁶

Botswana

Botswana has a growing economy and population that have become the main drivers of waste generation. According to Kgosiesele and Zhaohui,⁴⁷ high consumption rates in Botswana have resulted in the country being one of the largest producers of solid wastes in Africa. MSW is the most-generated type of waste. The main approach to dealing with solid waste in Botswana is through land filling, which is considered an inexpensive and traditional method. Some 175 waste-disposal sites are found throughout Botswana, with only two being properly engineered landfills. Gwebu⁴⁸ mentions that there is growing evidence of the illegal shipment of hazardous waste across international borders, and that Botswana, together with many other developing countries, is becoming a dump site. Although information about the effects of hazardous waste in Botswana is not available, some government reports have nevertheless stated that environmental problems in certain areas were probably related to infection caused by improper disposal of hospital wastes and/or pollution of underground water by waste oils.

Recycling in African Countries

Recycling has encouraged re-use of materials, instead of encouraging the acquisition of virgin material. World wars and other disasters have caused financial crises and resource shortages, which have necessitated alternative measures, such as the recycling of products. This was further encouraged by resource-conservation programmes established during the wars. Rising energy costs further promoted recycling. The

major advantage of this approach was observed in the recycling of aluminium; a process which uses only five per cent of the energy that would otherwise have been used for the processing of virgin materials. The potential for significant energy savings has been demonstrated.

Uncontrolled and unmonitored urbanisation has resulted in serious waste-disposal problems for developing Asian and African countries, which are aggravated by a lack of sufficient financial and human resources required for the collection, transportation, processing and final disposal of solid waste. The aspects of recycle, re-use and recovery of solid waste in these countries are, in most cases, dependent on the demand and supply of materials. It should also be noted that waste generated in developing African countries is similar in composition to that in other developing countries, with the variation being largely due to climatic conditions, cultural factors and, in some cases, industrial, infrastructural and legal factors. Informal waste-recycling is a common way to earn a living in the urban regions of African countries; one per cent of the urban population survives by salvaging recyclables from waste sites. Many developing nations practise resource recycling and re-use in the same way as past generations have done, as opposed to the type of recycling and re-use one finds in many more developed countries. The method of recycling and re-use in developed countries is done out of necessity and driven by low income and limited resources, compared to the situation in developed countries, where recycling is part of legislation for certain materials.

The Recycling Process

Recycling is the process whereby discarded products and materials are reclaimed, recovered, refined or reprocessed and converted into new or different products. This method, also known as external recovery of post-consumer and post-production waste, is an important part of the waste-management hierarchy.⁴⁹ The major objectives of recycling are, in general, to save resources as well as to reduce the environmental impact of waste by diverting a portion of the waste going to the landfill. Recycling has the potential to generate employment and help curb poverty, save governments and local authorities money, and improve healthy competition.

As part of modern technology, consumer goods are manufactured nowadays using materials that are either synthetic or not common in the environment in unusually high concentrations, and these goods are therefore potentially hazardous when left to decompose in open dumps or even landfills. The major problem is that developing countries lack the know-how and technology required to handle these increasing quantities of waste. This is largely due to their weak economies, as well as often having poor financial management and administrative capacity,⁵⁰ which consequently affects their ability to enforce environmental legislation. The word 'waste' is often

inappropriate in developing countries, since the economies of these countries dictate that materials and resources must be used to their full potential, prompting a culture of re-use, repair and recycling. As such, there exists a whole mechanism by which recyclers, scavengers and collectors function and interact; their essential objective is to recover and ultimately salvage waste and reclaim it for further use as raw material.

Recycling in Developing African Countries

In developing African countries, reclamation of recyclable materials is an important source of revenue for many people, but it should be noted that the level of reclamation varies substantially between the different countries. There is no source-separation of waste being done in such a way that all the waste is collected and transported to landfill sites or open dumps. Owing to the large quantities of recyclable materials found in waste streams, informal salvaging (scavenging) takes place.

Nigeria

Awareness of the need for an integrated waste-management system is already reaching many organisations. In the past, recycling revolved around the activities of scavengers, who used to collect scrap metal, rubber, paper and paper board, glass, leather, textiles and wood from different sources, including garbage bins, dump sites, markets and factories, and eventually recycle them into household and industrial products. Consequently, the demand for scrap materials from local iron and steel companies, as well as plastics manufacturers, together with importers from Asia and Latin-America, has increased, thereby increasing the uptake of recycling over the past two decades. A survey by Umaru,⁵¹ done in 2007, observed that recyclables, collected throughout the country, are partly for local use, but that the majority of recyclable materials are destined for overseas markets. This growing recycling trend is bound to persist and make an appreciable contribution to the Nigerian economy. Even though its contribution and emerging importance, in terms of employment opportunities, income and tax revenue generation is significant, this activity is yet to flourish and become a major component of the core economy, and is still treated as part of the informal sector. This may be mainly due to a lack of robust and adequate institutional arrangements, support and follow-up.

Uganda

In the capital, Kampala, materials considered refuse according to Western standards are re-used or recycled. Old tyres are converted into sandals, while old tin containers are transformed into paraffin candle holders. Other examples of the alteration of waste include plastic containers being turned into feeding-troughs for chickens. Household utensils are fabricated from scrap metal, and paper is recycled into toilet

tissue and wrapping paper. Industrial recycling of scrap metal is also being practised at dedicated sites. It should also be noted that organic materials are considered re-usable in developing countries: green vegetable matter, such as banana peels, pineapple, cabbage and some leftover food, is collected by farmers to be used as food for their animals, mainly pigs and cattle.⁵²

Kenya

Kenya's urban population is concentrated in three major cities and two towns. According to the government of Kenya, the rate of urbanisation has increased significantly. This represents a significant rural-urban migration rate. The growth of MSW generation has been rapid, while the capacity to collect and safely dispose of the material has declined. This is mainly due to the country's inability to maintain all its MSW trucks at full operational capacity. Recycling provides a cheaper source of raw materials for manufacturing industries, owing to the increasing price of raw materials. Kenya also has its share of intense scavenging, which is driven mainly by poverty and a desire to earn a living. The arrival of recycling industries in the country has given an incentive to scavengers to search for recyclable materials at dump sites. However, due to a frequent lack of water and electricity, another industry (making glue from bones and hooves provided by a nearby slaughterhouse) had to close down.⁵³

Conclusion

The conventional approach, where municipal authorities take over SWM, seems to be a more common practice in many African countries. The non-involvement of major stakeholders worsens the scenario throughout the continent and gives rise to several environmental, social and economic issues, which require well-planned strategies of SWM from a holistic perspective. This chapter also underpins the view that most African countries do not have a firm grip on any sustainable method of municipal SWM. It is all a history of trials and unfortunate or premature abandonment, with many issues seemingly unresolved. Africa's national and urban governments are mapping global strategies and technologies directly, but these are simply not suited to the local realities in many African communities. They are not adequately exploring, adapting and using local initiatives and domestic strategies, which could be expected to bring about significant improvement in SWM, in order to alleviate their specific issues and concerns. Local and adapted techniques, involving close and sustained collaboration with stakeholders and co-ordinated by the government, would be crucial to address the SWM challenges if Africa is to march on towards a

greener future where waste is minimised and unavoidable quantities are treated as recoverable resources.

Theoretical and practical considerations tend to indicate good scope for public–private partnerships in the SWM sector in African countries, but this is yet to be tapped judiciously. However, the conventional approach to public–private partnerships, whereby large conglomerates and government agencies link up initially to achieve one or more common goals, may need to be modified to accommodate communities at large. Communities are indispensable entities in SWM, if Africa is to adopt a sustainable strategy to address the related issues. A more adapted and well-planned SWM mechanism of operation and interaction between small-scale operators and the public sector may offer a better choice in these countries. The expertise of ‘success-story’ countries may be legitimately sought, and local African experts and decision-makers enlisted to produce more sustainable SWM strategies. A new set of incentives must be designed to foster healthy and effective knowledge and technology transfer, for both the private and public sector in African communities. Other severe barriers to meaningful partnerships include weak structural, financial and legal frameworks, which otherwise are meant to enhance and fuel sustainable waste management initiatives. These weaknesses provide unavoidable outlets for the lack of transparency amongst institutions and all stakeholders, poor fairness and absence of clear and inadequate accountability in the entire waste-management supply chain. Hence, the need to develop strong local, regional and international partnerships that are highly dynamic and adjust themselves to new African situations, should be an imminent and unalterable approach to ensure the required capacity-building. Consolidated capacity-building would not only require more research and advocacy amongst all groups involved, but political will and popular support would be a *sine-qua-non* if African countries are to breathe freely, in well-managed solid waste heaps.

Notes and References

- 1 Igoni, A.H., Ayotamuno, M.J., Ogaji, S.O.T. & Probert, S.D., 2007. Municipal solid-waste in Port Harcourt: Nigeria. *Applied Energy*, 84(6), pp.664–70.
- 2 Senkoro, H., 2003. *Solid Waste Management in Africa: A WHO / AFRO Perspective*. CWG Workshop. March 2003. Dar Es Salaam.
- 3 Schubeler, P., 1996. *Conceptual framework for municipal solid waste management in low-income countries*. St. Gallen: SKAT.
- 4 Zurbrugg, C. & Schertenleib, R., 1998. *Main problems and issues of municipal solid waste management in developing countries, with emphasis on problems related to disposal by landfill*. Third Swedish Landfill Research Symposia. October 1998. Luleå.

- 5 Medina, M., 2010. *Solid Wastes, Poverty and the Environment in Developing Country Cities: Challenges and Opportunities*. Helsinki: United Nations University.
- 6 Blight, G.E. & Mbande, C.M., 1996. Some problems of waste management in developing countries. *Journal of Solid Waste Technology and Management*, 23, pp.19–27.
- 7 Ezeah, C. & Roberts, C.L., 2012. Analysis of barriers and success factors affecting the adoption of sustainable management of municipal solid waste in Nigeria. *Journal of Environmental Management*, 103, pp.9–14.
- 8 Khalid, A., Arshad, M., Anjum, M., Mahmood, T. & Dawson, L., 2011. The anaerobic digestion of solid organic waste. *Waste Management*, 31(8), pp.1737–44.
- 9 Khanal, S.K., 2008. Overview of Anaerobic Biotechnology. In S.K. Khanal (Ed.), *Anaerobic Biotechnology for Bioenergy Production*. Oxford: Wiley-Blackwell.
- 10 Monnet, F., 2003. *An Introduction to Anaerobic Digestion of Organic Wastes*. Scotland: Remade.
- 11 Kelleher, B.P., Leahy, J.J., Henihan, A.M., O'Dwyer, T.F., Sutton, D. & Leahy, M.J., 2000. Advances in poultry litter disposal technology: A review. *Bioresource Technology*, 83, pp.27–36.
- 12 Chen, Y., Cheng, J.J. & Creamer, K.S., 2008. Inhibition of the anaerobic digestion process: A review. *Bioresource Technology*, 99, pp.4044–64.
- 13 Bouallagui, H., Touhami, Y., Cheikh, R.B. & Hamdi, M., 2005. Bioreactor performance in anaerobic digestion of fruit and vegetable wastes. *Process Biochemistry*, 40, pp.989–95.
- 14 Ward, A.J., Hobbs, P.J., Holliman P.J. & Jones, D.L., 2008. Optimisation of the anaerobic digestion of agricultural resources. *Bioresource Technology*, 99, pp.7928–40.
- 15 Amigun, B., Sigamoney, R. & von Blottnitz, H., 2008. Commercialisation of biofuel industry in Africa: A review. *Renewable and Sustainable Energy Reviews*, 12, pp.690–711.
- 16 Omer, A.M. & Fadalla, Y., 2003. Biogas energy technology in Sudan. *Renewable Energy*, 28, pp.499–507.
- 17 Mbuligwe, S.E. & Kassenga, G.R., 2004. Feasibility and strategies for anaerobic digestion of solid waste for energy production in Dar-es-Salaam city, Tanzania. *Resources, Conservation and Recycling*, 42, pp.183–203.
- 18 Müller, C., 2007. Anaerobic Digestion of Biodegradable Solid Waste in Low and Middle-Income Countries: Overview over existing technologies and relevant case studies. *Ewag*. Available at: http://www.eawag.ch/forschung/sandec/publikationen/swm/dl/Mueller_2007.pdf [Accessed 10 January 2013].
- 19 Hoornweg, D., Thomas, L. & Otten, L., 2000. *Composting and its Applicability in Developing Countries* (Waste management working paper series no. 8). Washington: World Bank.
- 20 Center for Clean Air Policy (CAP), 2012. Tackling Waste through Community-Based Composting: Bangladesh. *CCAP*. Available at: http://ccap.org/assets/CCAP-Booklet_Bangladesh-Compost.pdf [Accessed 6 February 2013].
- 21 Rogger, C., Beaurain, F. & Schmidt, T.S., 2011. Composting projects under the Clean Development Mechanism: Sustainable contribution to mitigate climate change. *Waste Management*, 31, pp.138–46.
- 22 Karagiannidis, A., Theodoseli, M., Malamakis, A., Bilitewski, B., Reichenbach, J., Nguyen, T., Galang, A. & Parayno, P., 2010. Decentralised aerobic composting of urban solid wastes: Some lessons learned from Asian-EU cooperative research. *Global NEST Journal*, 12, pp.343–51.

- 23 Mbuligwe, S.E., Kassenga, G.R., Kaseva, M.E. & Chaggu, E.J., 2002. Potential and constraints of composting domestic solid waste in developing countries: Findings from a pilot study in Dar-es-Salaam, Tanzania. *Resources, Conservation and Recycling*, 36, pp.45–59.
- 24 Oberlin, A.S. & Szántó, G.L., 2011. Community level composting in a developing country: Case study of KIWODET, Tanzania. *Waste Management and Research*, 29, pp.1071–7.
- 25 Cofie, O. & Koné, D., 2009. *Co-composting faecal sludge and organic solid waste Kumasi, Ghana -Case study of sustainable sanitation projects*. Eschborn: SuSanA.
- 26 Ecosurafrique, 2010. *Composting Plant CDM Project Signed with Zoomlion* [Press release]. 26 October 2010. Accra.
- 27 Taiwo, A.M., 2011. Composting as a sustainable waste management technique in developing countries. *Journal of Environmental Science and Technology*, 4, pp.93–102.
- 28 Rand, R., Haukohl, J. & Marxen, U., 2000. *Municipal Solid Waste Incineration: A Decision Maker's Guide*. Washington: World Bank.
- 29 United Nations Environment Programme (UNEP), 1996. *International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management*. Nairobi: UNEP.
- 30 Frey, H.H., Peters, B., Hunsinger, H. & Verhlow, J., 2003. Characterisation of municipal solid waste combustion in a grate furnace. *Waste Management*, 23, pp.689–701.
- 31 Ruth, L.A., 1998. Energy from municipal solid waste: A comparison with coal combustion technology. *Progress in Energy and Combustion Science*, 24, pp.545–64.
- 32 Fobil, J.N., Carboo, D. & Armah, N.A., 2005. Evaluation of municipal solid wastes (MSW) for utilisation in energy production in developing countries. *International Journal of Environmental Technology and Management*, 5, pp.76–86.
- 33 Ogwueleka, T.C., 2009. Municipal solid waste characteristics and management in Nigeria. *Iranian Journal of Environmental Health, Science and Engineering*, 6, pp.173–80.
- 34 Ogwueleka, T.C., 2003. Analysis of urban solid waste in Nsukka, Nigeria. *Journal of Solid Waste Technology and Management*, 29, pp.239–46.
- 35 Regassa, N., Sundaraa, R.D. & Seboka, B., 2011. Challenges and opportunities in municipal solid waste management: The case of Addis Ababa City, Central Ethiopia. *Journal of Human Ecology*, 33, pp.179–90.
- 36 Achankeng, E., 2003. *Globalisation, Urbanisation and Municipal Solid Waste Management in Africa*. African Studies Association of Australasia and the Pacific 2003 Conference Proceedings – African on a Global Stage. Adelaide: University of Adelaide. Available at: http://www.inclusivecities.org/wp-content/uploads/2012/07/Achankeng_Globalisation_Urbanisation_MSW_Mgmt.pdf [Accessed 15 January 2013].
- 37 Berkun, M., Aras, E. & Nemlioglu, S., 2005. Country report disposal of solid waste in Istanbul and along the Black Sea coast of Turkey. *Waste Management*, 25, pp.847–55.
- 38 Tinmaz, E. & Demir, I., 2006. Research on solid waste management system: To improve existing situation in Corlu Town of Turkey. *Waste Management*, 26, pp.307–14.
- 39 Al-Khatib, I.A., Arafat, H.A., Basheer, T., Shawahneh, H., Salahat, A., Eid, J. & Ali, W., 2007. Trends and problems of solid waste management in developing countries: A case study in seven Palestine districts. *Waste Management*, 27, pp.1910–9.
- 40 Sufian, M.A. & Bala, B.K., 2007. Modelling of urban solid waste management system: The case of Dhaka city. *Waste Management*, 27, pp.858–68.
- 41 Remigios, M.V., 2010. An overview of the management practices at solid waste disposal sites in African cities and towns. *Journal of Sustainable Development in Africa*, 12, pp.233–9.

- 42 Henry, R.K., Yongsheng, Z. & Jun, D., 2006. Municipal solid waste management challenges in developing countries: Kenyan case study. *Waste Management*, 26, pp.92–100.
- 43 Ecoforum, 2001. Lake Victoria: Economic Lifeline. *Regional Toilet*, 25(2), pp.27–37.
- 44 Agunwamba, J.C., 1998. Analysis of scavengers' activities and recycling in some cities of Nigeria. *Environmental Management*, 32, pp.116–27.
- 45 Adegbola, A.A. & Oladeji, O.S., 2012. Investigating groundwater quality around Olusosun dump site, Lagos State, Nigeria. *Indian Journal of Innovations and Development*, 1, pp.700–5.
- 46 Oladapo, O.O., Oni, E.A., Olawoyin, A.A., Akerele, O.O & Tijani, S.A., 2012. Assessment of natural radionuclides level in wasteland soils around Olusosun dump site Lagos, Nigeria. *IOSR Journal of Applied Physics* 2, pp.38–43.
- 47 Kgosiesele, E. & Zhaohui, L., 2010. An evaluation of waste management in Botswana: Achievements and challenges. *Journal of American Science*, 6, pp.144–50.
- 48 Gwebu, T.D., 2003. Population, development and waste management in Botswana: Conceptual and policy implications for climate change. *Environmental Management*, 31, pp.348–54.
- 49 Borland, J.E., Hanks, J., Wiechers, H.N.S. & Scott, W., 2000. *A framework for Sustainable Post-consumer Waste Recycling in South Africa*. Paper presented at the Waste Management of South Africa Conference. Somerset West.
- 50 Muniafu, M. & Otiato, E., 2010. Solid Waste Management in Nairobi, Kenya: A case for emerging economies. *The Journal of Language, Technology & Entrepreneurship in Africa*, 2, pp.342–50.
- 51 Umaru, I., 2010. Recycling of Solid Waste and the 'Yan Bola' Underground Economy: A survey of Environmental Entrepreneurs in Central Nigeria. *Journal of Human Ecology*, 30, pp.45–54.
- 52 Nyakaana, J.B., 1997. Solid Waste Management in Urban Centers: The case of Kampala City, Uganda. *East African Geographical Review*, 19, pp.33–43.
- 53 Rakodi, C., Gatabaki-Kamau, R. & Devas, N., 2000. Poverty and political conflict in Mombasa. *Environment and Urbanisation*, 12, pp.153–70.

CHAPTER 5

Moving up the Hierarchy: Involving the Informal Sector to Increase Recycling Rates in Nigerian Cities

Thaddeus Chidi Nzeadibe

Introduction

Solid waste management (SWM) is an urban issue, which often serves as a proxy indicator of the quality of city governance.¹ In many cities of the developing world, the informal sector plays an increasingly critical role in the management of solid waste. Services that companies and local governments are unable to provide in a sustainable way are sometimes provided by the informal sector,² while the public sector has often responded poorly to the growing demand for SWM in many developing country cities.³

In Nigeria, a cocktail of problems bordering on governance has contributed to producing and maintaining service deficits in the solid waste sector. Additionally, Nigerian cities do not have statutory resource recovery programmes, and as a result waste-collection and disposal remain inadequate.⁴ Waste recovery, collection and valorisation by the informal sector have come along to fill this gap, and also represent an important source of livelihood strategy for many living in these cities. Valorisation in this case refers to ‘the entire process of extracting, storing, collecting, or processing materials from the waste stream in order to extract and divert value and direct the material to a value-added stream.’⁵ The situation where SWM in Nigeria is being driven by the informal sector has recently been characterised as a case of ‘waste hierarchy from below’.⁶ Regrettably, contributions by the informal sector to waste reduction, recovery and recycling in Nigerian cities have remained largely unacknowledged.^{7,8}

While the informal sector is not officially recognised in SWM policy and planning, its activities in some Nigerian cities have become the focus of hostile urban governance policies, such as the ban on the activities of cart-pushers in Lagos.⁹ A major aim of the waste hierarchy is to reduce the amount of waste sent for disposal, while increasing recycling rates. Recycling can, therefore, rightly be described as a sustainable option in the waste hierarchy. This chapter demonstrates that the first step towards effective recycling is source separation. However, in the absence of statutory

requirements for waste segregation at source for recycling or disposal, the informal sector has become skilled at identifying materials with value and, as such, has been active in sorting recyclables. If the aim of modern waste management is to 'move up the waste hierarchy', then policies such as the recent prohibition of informal sector activities in Lagos, and the environmental injustices meted out to informal waste workers, would almost certainly drive the less determined to leave the valorisation trade. This would represent a significant setback to improved recycling performance. As Wilson et al. argue: It would seem ironic to move forward by deliberately eliminating what can be a rather efficient, existing recycling system.¹⁰

This study makes a case for involving the informal sector to increase recycling in Nigerian cities. It does this by drawing attention to the niche already carved by the informal recycling sector, arguing that the informal sector represents current possibilities and future strategy to increase recycling rates in Nigeria.

Overview of Informal Waste Management in African Cities

Background information on informal waste management (IWM) in Africa acts as an introduction and stimulates broader interest in the subject, as well as contextualising the Nigerian IWM system. In this respect, it should be noted that a large and dynamic indigenous waste-management system exists in Africa, largely driven by the informal sector. In many African cities, millions of poor and less-privileged urban residents make a living from collecting, recycling, valorisation and disposal of solid wastes.^{11,12,13} Thus, irrespective of where it occurs on the continent, IWM is a value chain activity.¹⁴ In spite of it often being mired in controversy^{15,16,17} IWM has remained a subject of tremendous interest to urban development researchers, policymakers and practitioners in Africa. Figure 5.1 illustrates the collection of solid waste by the informal sector in Ouagadougou, Burkina Faso.

Figure 5.1: Collection of solid waste using donkey cart in Ouagadougou



(Source: Author, December 2008)

Unfortunately, one of the least-studied aspects of the world economy is the informal waste economy of the global South,^{18,19} and Africa in particular.²⁰ While recent research argues that informal economies have become more deeply enmeshed in international commodity circuits, sometimes propelled by global structures and processes of change,^{21,22} these trends have led to new opportunities for some groups, but have at the same time increased the vulnerability of many in Africa.^{23,24,25}

IWM is an important and significant livelihood activity in many countries in Africa. Although not specifically listed among the Millennium Development Goals (MGDs) adopted in 2000 as indicators of global development,²⁶ IWM has come to be recognised as a cross-cutting development issue, and has been shown to have remarkable linkages with some of the goals.^{27,28} The 12-year period between 2000 and 2012, which represents about 80 per cent of the time projected for the achievement of the United Nations (UN) MDGs, has been observed as particularly significant for informal sector recycling (ISR) systems as a major component of IWM. According to Scheinberg,²⁹ 'the global informal recycling sector ceased to be invisible, and came into focus as the base of the industrial value chain'.

In addition, since the turn of the twenty-first century in urban Africa, there has been an upsurge in research into reclaiming reusable and recyclable materials across the continent.³⁰ The period under reference marked an era of productive research, scholarship and activism about global IWM systems.^{31,32} These had consequential, trickle-down effects, while the African continent also benefited from the evolution and intensification of development research on IWM in its cities. However, whether this period of productive scholarship and activism was entirely coincidental, or triggered by specific factors, remains debatable.

On the other hand, African cities are increasingly characterised by low-density peripheral sprawl, economies dominated by informal activities, and widespread informal settlements with limited services.³³ Informality therefore remains a reality, which has long dominated many urban landscapes in Africa. Informality today, and perhaps even more importantly in the future, will continue to be the dominant mode of urban production in many cities of Africa.^{34,35} Consequently, should the increasing informality of cities represent a new mode of urbanism and the majority of the global population continue to be 'informal',³⁶ the question arises whether the informality of Africa's waste urban sector reflects the dysfunctionality of all African cities.

In seeking to shed more light on this it may be argued that, despite the lack of formal recycling systems, many African cities have demonstrated a great capacity for an effective informal system for waste recycling. Lending a voice to this, Adama-Ajonye³⁷ avers that, in spite of the common perception that African cities are dysfunctional, they do, in fact, function – though perhaps not in the way envisaged by current Western urban planning and development models. Regarding the collection, sorting and recycling

of waste by informal sector groups, it is pertinent to reiterate that IWM is a phenomenon prevalent in many African cities, and that it has remained a controversial issue in urban development and management over the years. In spite of this, some researchers insist that recycling of waste can be done successfully in African cities, and have gone on to show how this is currently being done. They further assert that informal- sector recycling has broader implications for urban livelihood and environmental sustainability in Africa.^{38,39} Benefits derived from IWM include reducing the quantities of waste sent for disposal, thereby driving entrepreneurship, generating employment and generating income. IWM also contributes to mitigating the problem of climate change, the creation of a 'green economy' and the conservation of non-renewable resources. On this score, some international organisations have recently argued strongly in favour of the inclusion of waste-pickers in the promotion of green jobs.⁴⁰ Thus, Medina⁴¹ maintains that IWM has the potential to do several things: create jobs; reduce poverty; save municipalities money; supply inexpensive materials to industry, thus improving its competitiveness; conserve natural resources; and help clean up the urban environment. These benefits arguably encompass the economic, environmental and social objectives of sustainability.

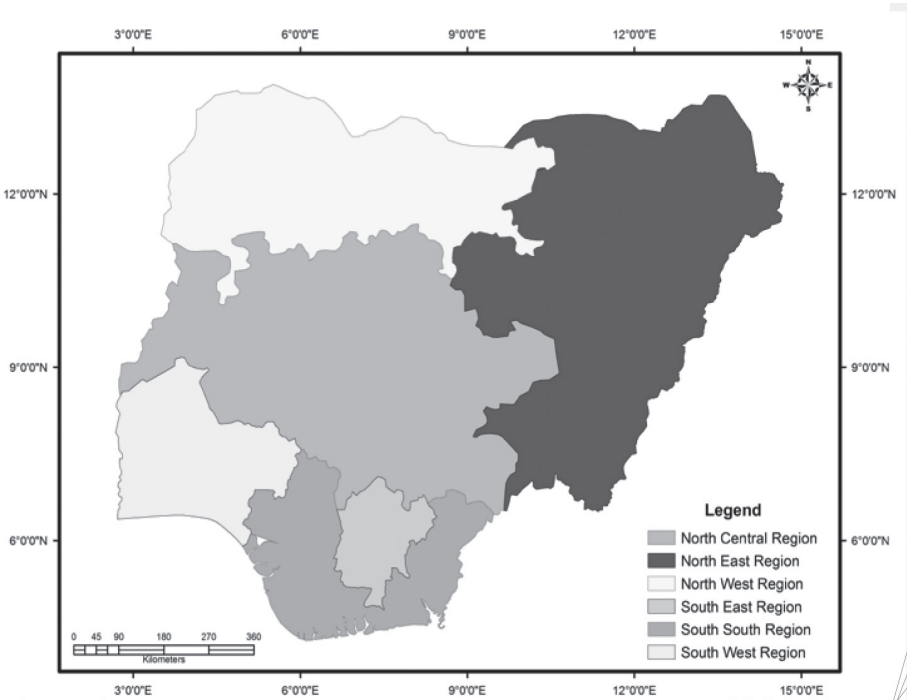
While waste management by the informal sector in Africa can often be innovative, Oguntoyinbo⁴² contends that the informal sector has not been integrated into an inclusive waste management system, which is a major limitation to social acceptance of the activity. Social acceptance of IWM as a legitimate economic activity in Africa is important in order to achieve the objective of an 'Inclusive City' – that is, a place where everyone, regardless of wealth, gender, age, race or religion is able to participate productively and positively in the opportunities the city has to offer. Social acceptance is therefore being canvassed, as it has been shown elsewhere that socially inclusive approaches to SWM and recycling, involving the informal sector in low-income and middle-income cities, can achieve spectacular results.^{43,44} This section of the chapter offers insight into the broader African IWM, as a prelude to discussion of the Nigerian system.

Focus on the Nigerian IWM Sector

Nigeria is made up of six geopolitical regions, with three each in the north and south, as follows: North East, North West, North Central, South East, South West and South South, as shown in Figure 5.2. The earliest informal sector recycling research in Nigeria related to scavengers in Ilorin.⁴⁵ Since then, academic research into informal recycling in Nigeria has examined different aspects of the recycling trade, such as the socio-economic aspects of the activity;^{46,47,48,49,50} socio-spatial organisation of scavenging and recyclables markets;^{51,52} the environmental aspects of

waste-picking;⁵³ the politics of informality and the social participation of recyclers in urban governance;^{54,55,56,57,58} vulnerability and quality of life assessments;⁵⁹ and the public health impacts of waste scavenging.⁶⁰

Figure 5.2: Map showing the six geopolitical regions of Nigeria



(Source: GIS laboratory, Department of Geography, University of Nigeria, Nsukka)

Table 5.1 presents the geographic distribution of refereed studies on Nigerian IWM systems. Criteria for inclusion in Table 5.1: include peer-review of journal articles, in order to reasonably guarantee the scholarly quality of the content; an explicit focus on Nigeria; and unambiguous discussion of waste-collection, recycling and municipal SWM by the informal sector. The table shows that the majority of studies dealing with the IWM system in Nigeria have focused on waste-pickers, with little attention being paid to other actors in the recycling system. A possible explanation of this may be the ubiquity of the activity in most Nigerian cities, which is directly traceable to the worsening socio-economic conditions which appear to intensify waste-picking during the first decade of the twenty-first century, and the recent upsurge of urban research interest on the interconnections between poverty, livelihood and development. In this context, the waste-pickers would seem to represent the quintessential urban poor, although some researchers have also noted their potential development contributions.

Table 5.1: Distribution of peer-reviewed publications on Nigerian IWM system

City/Geographic entity	No. of studies	Authors	Focus group/Region
Aba	2	Nzeadibe & Anyadike, 2012; Nzeadibe et al., 2012	Waste-pickers and scrap dealers/ South East
Nsukka	3	Agunwamba, 2003; Nzeadibe, 2009b; Nzeadibe & Ajaero, 2011	Waste-pickers / South East
Kaduna	1	Adama 2012	Informal waste workers/North West
Enugu	2	Agunwamba 2003; Nzeadibe 2009a	Waste-pickers/ South East and South South
Port Harcourt	2	Agunwamba 2003; Ogbonna 2008 ⁶¹ ; Wilson et al., 2009	Waste-pickers and IWBs/South South
Abuja	2	Imam 2008 ⁶² ; Ezeah and Roberts 2012 ⁶³	Waste-pickers/ North Central
Onitsha	2	Agunwamba 2003; Nzeadibe & Eziuzor 2006	Waste-pickers/ South East
Awka	1	Muoghalu & Okoye 2010	Waste-pickers/ South East
Owerri	1	Nzeadibe et al 2010	Waste-pickers/ South East
Lagos	5	Kofoworola 2007; Nzeadibe & Iwuoha 2008; Nzeadibe & Anyadike 2010; Afon 2007, 2012	Cart-pushers and waste-pickers/ South West
Central Nigeria	1	Umaru 2010	Waste-pickers/ North Central
Nigerian cities	3	Ogwueleka 2009; Agbo 2011 ⁶⁴ ; Oguntoyinbo 2012	Informal recycling in different Nigerian cities
Ilorin	1	Adeyemi et al 2001	Waste-pickers/ South West
Total	26		

(Source: Author's compilation from different sources)

On the other hand, the political economy of IWM may be linked to the poor performance of the formal solid waste collection, recycling and disposal system in Nigerian cities. This may be attributed, in turn, to governance problems, as well as a tangible shortfall in local governments' financial resources. As a result, municipalities are unable to provide these critical urban environmental services on a sustainable basis,⁶⁵ which contributes to producing and perpetuating service deficits in the waste sector.

The question arises whether or not the absence of formal services represents a blanket dysfunctionality of urban Nigerian waste management systems. In this regard Duminy⁶⁶ observes that informal recycling can contribute to economic growth by driving entrepreneurship, employment, and income generation, as well as effective urban environmental management. The author further notes that the overall efficiency of urban SWM benefits from informal recycling, operating in parallel with formal collection and disposal systems. In light of this observation, this chapter does not subscribe to the notion that IWM in itself indicates dysfunctionality of Nigerian cities: rather, that the existence of deficits or the absence of SWM services has often created opportunities for the provision of such services by informal recyclers. Hence, the informal sector has remained active in solid waste collection and disposal, while the only form of public recycling is that which is undertaken by informal waste workers.⁶⁷ Consequently, IWM practices in Nigeria are perceived as an integral part of a dynamic urban processes of production, consumption and recovery. Figure 5.3 illustrates the transportation from Abuja to Lagos of recyclables by scrap dealers.

Figure 5.3: Transportation of scrap metals in Nigeria



(Photo: Johan Sävström and the Nordic Africa Institute, Uppsala)

Informal Sector Recycling Performance in Nigeria

Data regarding informal sector activities and performance are notoriously scarce and, where available, often unreliable. In this context, Wilson, et al.⁶⁸ are of the view that the informal sector, almost by definition, does not routinely measure its performance. However, Table 5.2 presents a summary of available estimates of the recycling performance of diverse, informal sector groups in urban Nigeria. These estimates are sourced from various peer-reviewed publications on the informal waste-recycling sector in Nigeria.

Currently, no reliable statistical data exist for the recycling economy in Nigerian cities. Recent estimates on the informal recycling economy in Nigeria involved empirical research, with limited data and prior knowledge available, regarding informal waste-recycling activities. In the absence of reliable official data on recycling performance, research is inhibited by these estimates and the data have to be treated with caution, as there are significant gaps in the data-set presented. In spite of this limitation, the data presented are the best possible, in a rather difficult situation. As noted by Wilson et al.,⁶⁹ Nigeria provides an example of where the informal sector is achieving relatively low, yet significant, recycling rates. Evidence from available data indicates a clear potential to build up recycling rates, and the informal sector represents current possibilities and a future strategy to do this.

Table 5.2: Available estimates of informal sector recycling performance in Nigerian cities

City	Informal sector groups					
	Waste-pickers		Scrap dealers/ Middlemen		IWBs/Cart pushers	
	Av. Qty of materials (tonnes)	Approx. Annual Earning (US\$)	Av. Qty of materials (tonnes)	Approx. Annual Earning (US\$)	Av. Qty of materials (tonnes)	Approx. Annual Earning (US\$)
Aba	-	3944 ^b	-	6663 ^b	-	-
Lagos	1168.94 ^g	1575 ^f	-	-	-	5625 ^f
Onitsha	74.4 ^h	1019 ^c	-	-	-	-
Enugu	41.5 ^c	1192 ^c	-	-	-	-
Port Harcourt	-	510 ^e	-	4248 ^e	-	3058 ^e
Nsukka	-	1848 ^a	24.15 ^a	9840 ^a	-	-
Kaduna	-	6660 ^d	-	-	-	-

(Sources: ^aNzeadibe and Ajaero, 2011; ^bNzeadibe and Anyadike, 2012; ^cNzeadibe, 2009; ^dAdama, 2012; ^eWilson et al., 2009; ^fAfon, 2007 (however, Nzeadibe and Iwuoha (2008) estimate annual earnings of US\$788 for cart pushers in Lagos); ^gNzeadibe and Iwuoha, 2008; ^hNzeadibe and Eziuzor, 2006)

Innovative Niches of the Nigerian Recycling Economy

In many cities around the world, individuals and small groups have emerged to develop and implement solutions to pressing social and economic challenges through what has been referred to as 'social innovation'.⁷⁰ The general, social rationale of collective innovative initiatives is to promote inclusion into different spheres of society, while the political rationale is to give a 'voice' to groups that are traditionally absent from politics and the politico-administrative system at local and other institutional/spatial levels.⁷¹

In the social sciences, social innovation is often related to inventive solutions to poverty alleviation or social exclusion.⁷² The social entrepreneur provides a product or service that fulfils a social need. It may consequently, be argued that there is an unfulfilled social need in solid waste governance which the informal sector strives or has managed to satisfy, often with the application of innovation, dexterity and entrepreneurship. Consequently, the informal sector in Nigeria is known to be inherently innovative and resilient under rather difficult circumstances.

Although Onyenechere⁷³ asserts that because there are only a few well-documented case studies of contributions of informal sector activities, attention has been drawn to some neglected aspects of research in that sector, especially those that relate to the environment in general. Recent studies have reviewed the innovative niches of the informal waste sector in urban Nigeria,⁷⁴ and have chronicled developments in four decades of research on the informal sector as a whole, with some discussion of IWM.⁷⁵ In addition to this, there is the more recent exploration of the activities of the IWM sector in Nigeria, and barriers to their integration into an inclusive waste management system.⁷⁶

In the absence of official data on the number of people involved, attempts have recently been made to estimate the population of informal waste-collectors and recyclers in some Nigerian cities. In Lagos, for example, the figure has varied between 3 000 and 5 000.⁷⁷

Cart-pushers (locally known as *kole-kole* or *barro* boys), estimated to number more than 5 000, are active in the collection and disposal of waste, accounting, in some cases, for more than 70 per cent of the waste disposal in some parts of the city, and they have been reported to be popular among the residents of Lagos.

It is also argued that, when compared with the formal sector, the informal waste sector provides employment opportunities for a significant number of people. For example, while the number of workers directly⁷⁸ on the payroll of the Lagos State Waste Management Authority (LAWMA) was estimated to be about 2 000, as at July 2009,⁷⁹ the population of waste-pickers in Lagos is estimated to be 3 000.⁸⁰ In contrast to this, Afon⁸¹ provides a figure of 1 243, noting that they are found mainly at the Olusosun landfill site. On the other hand, waste-pickers and scrap dealers in

the city of Aba are estimated to number 600 and 195 respectively.⁸² Beyond these estimates, the population of informal waste workers in other Nigerian cities remains unknown. Figure 5.4 shows a waste-picker in the Nigerian commercial city of Aba.

Figure 5.4: A waste-picker at the BTC dump, Faulks Road, Aba



(Source: Author's fieldwork, 2006)

It is pertinent to note that before now – with little support from development agencies, no official recognition by government, and the social stigma associated with their work⁸³ – the informal waste sector in Nigeria seems to recognise that its survival depends on the adoption of new, ‘internally-generated’ ideas and governance arrangements.⁸⁴ The formation and operation of a vibrant, co-operative association by informal sector groups in Lagos may be regarded as a form of social innovation.⁸⁵ Locally formed and adapted characteristics and social systems appear to have enabled the sector to tide over the diversity of the recycling trade. Most prominent of these are a participatory, socio-political organisation and networking among informal waste workers, economic and socio-environmental contributions, and resilience in the face of an unfavourable socio-economic and political climate.⁸⁶

The recent support of international and local non-governmental organisations (NGOs) has galvanised an effort to organise informal waste workers in some Nigerian cities.^{87,88} One such effort is the *Waste-collection Workers Welfare Initiative*,⁸⁹ which aims to cater for the welfare of waste-pickers. According to the founder, the initiative aims to enable waste-pickers to have a group voice in the liberalisation of the sales of their products, as well as to provide a forum for meaningful engagement with

government, chiefly for security purposes. This initiative has reportedly enlisted the support of the state, in order to improve the deplorable working and living conditions of the waste-pickers. It is currently being run from the city of Lagos, with plans to expand to other Nigerian cities.

In a related development, the Mabushi district of Abuja has one of the many unofficial transfer stations for waste that can be sold or recycled.⁹⁰ Five hundred people live and work at this scavenger settlement. This author reports that waste-pickers in the area have been involved in the formation of the National Association of Scavengers (NAS), which aims to unite waste-pickers in Nigeria and change their informal status through advocacy work. Another group of 150 waste-pickers at the Gosa waste disposal site have reportedly been registered by the Abuja Environmental Protection Board (AEPB) to recover materials at the site, and belong to a recognised association.⁹¹ Figure 5.5 depicts the scavenger settlement in Mabushi district of Abuja.

Figure 5.5: Scavenger settlement in Mabushi showing recyclables in the foreground



(Photo credit: Johan Sävström and the Nordic Africa Institute, Uppsala)

Again, civil society organisations, such as the Federation of Informal Workers' Organisations of Nigeria (FIWON) and Women in Informal Employment: Globalising & Organising (WIEGO), have formed partnerships to collect information on waste-pickers in Nigeria.⁹² FIWON already organises informal traders, and some of its members have now established the best way to obtain information concerning waste-pickers, through WIEGO. FIWON members often share the same space as pickers when selling their goods in markets and on the streets. In March 2012, an official

of WIEGO trained FIWON members for two days on how to identify, contact and collect information on waste-picker organisations and support groups in Nigeria. A mini-workshop was also organised, in which the process of mapping waste-picker groups was initiated.⁹³ From the foregoing, in the absence of sustainable solutions from the formal sector,⁹⁴ it can be concluded that the informal waste sector appears to have carved out a niche, inserting itself into the solid waste governance paradigm in many Nigerian cities. The present study underscores this current role and potential input, in a future strategy to increase recycling rates in Nigeria.

Interventions to Improve Lives and Recycling Rates in Nigeria

The recommended development interventions are derived from issues raised by informal waste workers themselves during dumpsite Focus Group Discussions (FGDs), and from a synthesis of key responses to questions by Nigerian environment and development policy experts during key informant interviews (KIIs). Although the interventions were suggested in the context of the city of Aba, the measures are equally applicable to other Nigerian cities. The recommendations are reproduced in Table 5.3.

Table 5.3: Some interventions in the informal waste sector in Aba, Nigeria⁹⁶

Recommended development intervention	Nature of intervention	Implementing/facilitating agency	Suggested timelines
Policy-level recognition of informal sector in SWM	Legislative and institutional reform of SWM	Abia State Govt. with support of development agencies	2 years
Advocacy for the informal sector	Campaigns, workshops, lobbying and awareness-raising	NGOs and University Researchers on SWM	Immediate and continuous
Provision of basic amenities	Vaccination, water, sanitation and health care	Development agencies/NGOs	Immediate
Provision of means of transporting recovered materials	Tricycles, carts and cycle rickshaws	Development agencies/NGOs	Immediate
Improvement in recycling rates	PPP, buy-back schemes,	ASEPA/Govt.	Immediate and continuous
Organising scavengers into co-ops	Provision of grants, Technical assistance/management advice and guidance	Development agencies/NGOs	Immediate

(Source: Nzeadibe and Anyadike 2012)

Conclusions

This chapter concludes that the only form of public recycling currently in Nigeria is that which is being done by the informal sector. This informal sector in urban Nigeria is skilled at identifying materials of value, and has been recovering recyclables from the waste stream. If this proposition is accepted, the next logical step will be to involve the existing informal sector to scale up and perhaps refine what they are already doing, for improved recycling performance. A change in the attitude of citizens and governments and support for the informal recycling sector is canvassed. In view of their development contributions, which are made with little or no support, informal waste workers in Nigeria need to be seen, not as a nuisance to society, but as active players in the urban socio-economic space.

Given the extensive availability of waste, the prevailing harsh economic situation, disparity in income distribution and the sheer need to survive in Nigeria, the inevitable existence of informal sector recycling in the country is hardly surprising. Social acceptance of this reality allows viewing it as a basis of further development rather than as an impediment to development. In the light of available knowledge and empirical evidence, this study suggests that acknowledging and incorporating informal workers into new ways of delivering SWM services could yield sustainable solutions – in this case, improved recycling rates.

Happily, seeds of organising of the waste workers have been sown, although there is as yet no synergy among the different agencies. Therefore it will make a lot of sense and significantly help their cause if the individual waste-picker organisations would coalesce, so as to improve their negotiating power and exchange ideas and information. Perhaps Nigeria should emulate countries such as Brazil, which have made tremendous socio-economic progress and achieved spectacular results through socially-inclusive policies and approaches to SWM involving the informal sector. It is argued that the informal sector represents current possibilities and future strategy to increase recycling rates in Nigeria. Development interventions to make this happen have also been suggested.

Acknowledgements

The author wishes to express his gratitude to all the researchers whose data and publications have been used in the preparation of this chapter. The journal *City, Culture and Society* (Elsevier Publishers) is gratefully acknowledged for its permission to use Table 5.3 in this paper. Grateful thanks also go to Johan Sävström and Dr Onyanta Adama of the Nordic Africa Institute (NAI), Uppsala, Sweden for the use of photographs and for enriching discussions during my visit to the NAI as

African Guest Researcher. Finally, the author sincerely thanks Uchenna F. Ochege, of the Geography Department, University of Nigeria, Nsukka, for assistance with the cartographic work.

Notes and References

- 1 Gunsilius, E., & Whiteman, A., 2010. Waste management and governance: Collaborative approaches for public service delivery. In Scheinberg, A., Wilson, D.C. & Rodic, L. (eds.), *Solid waste management in the world's cities*, pp.187–90. London: Earthscan.
- 2 Scheinberg, A., Wilson, D.C. & Rodic, L., 2010. *Solid waste management in the world's cities*. London: Earthscan.
- 3 Ahmed, S.A. & Ali, M., 2004. Partnerships for solid waste management in developing countries: Linking theories to realities. *Habitat International*, 28(3), pp.467–79.
- 4 Ogwueleka, T.C., 2009. Municipal solid waste characteristics and management in Nigeria. *Iranian Journal of Environmental Health Science and Engineering*, 6(3), pp.173–80.
- 5 Ibid; Scheinberg, A., Wilson, D.C. & Rodic, L., 2010.
- 6 Adama, O., 2013. Informal recycling. In *Development Dilemmas: Annual Report 2012*, p.16. Uppsala: Nordic Africa Institute.
- 7 Nzeadibe, T.C., 2009a. Solid waste reforms and informal recycling in Enugu urban area, Nigeria. *Habitat International*, 33(1), pp.93–9.
- 8 Nzeadibe, T.C. & Ajaero, C.K., 2011. Development impact of advocacy initiatives in solid waste management in Nigeria. *Environment, Development and Sustainability*, 13(1), pp.163–77.
- 9 Nzeadibe, T.C. & Anyadike, R.N.C., 2010. Solid waste governance innovations: An appraisal of recent developments in the informal sector niche in urban Nigeria. *Geography Compass*, 4(9), pp.1284–96.
- 10 Wilson, D. C., Velis, C. & Cheeseman, C., 2006. Role of informal sector recycling in waste management in developing countries. *Habitat International*, 30(4), pp.797–808.
- 11 Dias, S., 2012. Waste and Development – Perspectives from the Ground. *Field Actions Science Reports*, [online] Special Issue 6, 20 June. Available at: <http://factsreports.revues.org/1615> [Accessed 6 August 2012].
- 12 Gutberlet, J., 2010. Waste, poverty and recycling. *Waste Management*, 30(2), pp.171–73.
- 13 Medina, M., 2007. *The world's scavengers: Salvaging for sustainable consumption and production*. Maryland: AltaMira Press.
- 14 Scheinberg, A., 2012. Informal Sector Integration and High Performance Recycling: Evidence from 20 Cities. *WIEGO Working Paper (Urban Policies)*, 23. Cambridge: WIEGO.
- 15 Samson, M., 2009. Refusing to be Cast Aside: Waste-pickers Organising around the World. *Women in Informal Employment: Globalising and Organising*. Cambridge: WIEGO.
- 16 Afon, A.O., 2007. Informal sector initiative in the primary sub-system of urban solid waste management in Lagos, Nigeria. *Habitat International*, 31(2), pp.193–204.
- 17 Fahmi, W.S & Sutton, K., 2006. Cairo's Zabaleen garbage recyclers: Multi-nationals' takeover and state relocation plans. *Habitat International*, 30(4), pp.809–37.

- 18 Brooks, A., 2012a. Riches from rags or persistent poverty? The working lives of second-hand clothing vendors in Maputo, Mozambique. *Textile: The Journal of Cloth and Culture*, 10(2), pp.222–37.
- 19 Brooks, A., 2012b. Stretching global production networks: The international second-hand clothing trade. *Environment, Politics and Development Working Paper Series*, 44. London: Department of Geography, King's College. Available at: <http://www.kcl.ac.uk/sspp/departments/geography/research/epd/WP44.pdf> [Accessed 29 August 2012].
- 20 WIEGO, 2012. *Waste Picking in Africa*, 2(1). Available at: http://globalrec.org/wp-content/uploads/2012/05/2012-04_newsletter-africa-english.pdf [Accessed 2 April 2013].
- 21 Ibid; Medina, M., 2007.
- 22 Medina, M., 2011. *Global Supply Chains in Chinese Industrialisation: Impact on Waste Scavenging in Developing Countries*, working paper no. 2011/78. Helsinki: UNU-WIDER.
- 23 Lindell, I., 2010. *Africa's informal workers: Collective agency, alliances and transnational organizing in urban Africa*. London: Zed Books.
- 24 Faninger, T., 2011. Reducing vulnerability of developing countries recyclers to global markets: A case study of plastic recyclers in Kenya. *Communications in Waste & Resource Management*, 12(1), pp.1–3.
- 25 Nzeadibe, T.C., Anyadike, R.N.C. & Njoku-Tony, R.F., 2012. A mixed methods approach to vulnerability and quality of life assessment of waste picking in urban Nigeria. *Applied Research in Quality of Life*, 7(4), pp.351–70.
- 26 United Nations, 2000. United Nations Millennium Development Goals. United Nations, [online]. Available at: <http://www.un.org/millenniumgoals/> [Accessed 7 April 2013].
- 27 Gonzenbach, B. & Coad, A., 2007. *Solid waste management and the millennium development goals: Links that inspire action*. St. Gallen: CWG Publication.
- 28 Ibid; Nzeadibe, T.C., 2009a.
- 29 Ibid; Scheinberg, A., 2012.
- 30 Samson, M.2010. *Reclaiming Reusable and Recyclable Materials in Africa: A Critical Review of English Language Literature* (Working paper no. 16). Massachusetts: WIEGO. Available at: http://wiego.org/sites/wiego.org/files/publications/files/Samson_WIEGO_WP16.pdf [Accessed 26 October 2012].
- 31 Ibid; Scheinberg, A., 2012.
- 32 Chamane, M., 2009. South Africa's waste-pickers: Creating jobs and fighting poverty. *The Workplace*, 33(2), pp.22–4. Available at: <http://www.inclusivcities.org/pdfs/SOUTH%20AFRICA%27S%20WASTE%20PICKERS%5B1%5D.doc> [Accessed 24 February 2010].
- 33 UN-HABITAT, 2009. *Planning Sustainable Cities: Global Report on Human Settlements 2009*. London: Earthscan.
- 34 Heintz, J. & Valodia, I., 2008. *Informality in Africa: A Review* (Working paper no. 3). Massachusetts: WIEGO.
- 35 Ejigu, A.G., 2011. *Coupling informality with formality: Ideas for innovative housing and urban development strategy*. 4th European Conference on African Studies (ECAS 4) African Engagements: On whose terms?. 15–18 June. Uppsala: The Nordic Africa Institute.
- 36 Revell, K., 2010. *Working with informality: increasing resilience in cities of the Global South*. 46th ISOCARP Congress 2010. Nairobi.
- 37 Adama-Ajonye, O., 2011a. *Recycling in African cities can work* [Press release]. 31 March. Uppsala: The Nordic Africa Institute. Available at: <http://www.mynewsdesk.com/se/pressroom/>

- nordiska_afrikainstitutet/pressrelease/view/recycling-in-african-cities-can-work-607616 [Accessed 10 November 2012].
- 38 Adama-Ajonye, O., 2011b. Beyond dysfunctionality: Recycling in Kaduna. In Lorentz, L. & Sköld, M. (eds.), *The rise of Africa: Miracle or mirage?: Annual Report 2010*. Uppsala: Nordiska Afrika institutet., pp.38–40.
 - 39 Adama, O., 2012. Urban livelihoods and social networks: Emerging relations in informal recycling in Kaduna, Nigeria. *Urban Forum*, 23(4), pp.449–66.
 - 40 International Labour Organisation, 2013. Promoting green jobs through the inclusion of informal waste-pickers in Chile. *International Labour Organisation*, [online]. Available at: http://www.ilo.org/empent/units/green-jobs-programme/about-the-programme/WCMS_216961/lang--en/index.htm [Accessed 9 August 2013].
 - 41 Ibid; Medina, M., 2007.
 - 42 Oguntuyinbo, O.O., 2012. Informal waste management system in Nigeria and barriers to an inclusive modern waste management system: A review. *Public Health*, 126, pp.441–7.
 - 43 Ibid; Scheinberg, A., Wilson, D.C. & Rodic, L., 2010.
 - 44 Scheinberg, A., Simpson, M., Gupta, Y., Anschütz, J., Haenen, I., Tasheva, E., Hecke, J., Soos, R., Chaturvedi, B., Garcia-Cortes, S. & Gunsilius, E., 2010. *Economic Aspects of the Informal Sector in Solid Waste Management*. Eschborn: GTZ.
 - 45 Adeyemi, A.S., Olorunfemi, J.F. & Adewoye, T.O., 2001. Waste scavenging in Third World cities: A case study in Ilorin, Nigeria. *The Environmentalist*, 21(2), pp.93–6.
 - 46 Ibid; Adama, O., 2012.
 - 47 Agunwamba, J.C., 2003. Analysis of scavengers' activities and recycling in some cities of Nigeria. *Environmental Management*, 32(1), pp.116–27.
 - 48 Muoghalu, L.N. & Okoye, A.C., 2010. Solid waste management and economic growth: A preliminary report of a case study of scavenging activity in Anambra State. *Tropical Built Environment Journal*, 1(1), pp.73–82.
 - 49 Umaru, I., 2010. Recycling of solid waste and the “Yan Bola” underground economy: A survey of environmental entrepreneurs in Central Nigeria. *Journal of Human Ecology*, 30(1), pp.45–54.
 - 50 Afon, A., 2012. A survey of operational characteristics, socioeconomic and health effects of scavenging activity in Lagos, Nigeria. *Waste Management & Research*, 30(7), pp.664–71.
 - 51 Nzeadibe, T.C. & Eziuzor, O.J., 2006. Waste scavenging and recycling in Onitsha urban area, Nigeria. *CIWM Scientific and Technical Review*, 7(1), pp.26–31.
 - 52 Nzeadibe, T.C. & Iwuoha, H.C., 2008. Informal waste recycling in Lagos, Nigeria. *Communications in Waste and Resource Management*, 9(1), pp.24–30.
 - 53 Kofoworola, O.F., 2007. Recovery and recycling practices in municipal solid waste management in Lagos, Nigeria. *Waste Management*, 27(9), pp.139–43.
 - 54 Ibid; Nzeadibe, T.C., 2009a.
 - 55 Ibid; Nzeadibe, T.C. & Ajaero, C.K., 2011.
 - 56 Nzeadibe, T.C., 2009. Development drivers of waste recycling in Nsukka urban area, Southeastern Nigeria. *Theoretical and Empirical Researches in Urban Management*, 3(12), pp.137–49. Available at: <http://www.um.ase.ro/No12/11.pdf> [Accessed 9 August 2013].
 - 57 Adama, O., 2011. *The politics of informality: An insight into the informal solid waste recycling sector in Kaduna, Nigeria*. 4th European Conference on African Studies (ECAS 4) African Engagements: On whose terms? 15–18 June. Uppsala: The Nordic Africa Institute.

- 58 Nzeadibe, T.C. & Anyadike, R.N.C., 2012. Social participation in city governance and urban livelihoods: Constraints to the informal recycling economy in Aba, Nigeria. *City, Culture and Society*, 3(4), pp.313–25.
- 59 Ibid; Nzeadibe, T.C., Anyadike, R.N.C. & Njoku-Tony, R.F., 2012.
- 60 Ezeah, C., Roberts, C.L., Phillips, P.S., Mbeng, L.O. & Nzeadibe, T.C., 2009. *Evaluation of public health impacts of waste scavenging in Abuja Nigeria using Q-Methodology*. Proceedings of the International Solid Waste Association (ISWA) World Congress 2009. 12–15 October. Lisbon. Available at: http://www.iswa.it/materiali/iswa_apesb_2009/6-358paper_long.pdf [Accessed 6 August 2012].
- 61 Ogbonna, D.N., 2008. Assessment of the activities and contributions of the waste-pickers / scavengers to solid waste management in Port Harcourt, Nigeria. *Niger Delta Biologia*, 8(1), pp.53–64.
- 62 Imam, A., Mohammed, B., Wilson, D.C., & Cheeseman C. R., 2008. Solid waste management in Abuja, Nigeria. *Waste Management*, 28(2), pp.468–72.
- 63 Ezeah, C., & Roberts, C.L., 2012. Analysis of barriers and success factors affecting the adoption of sustainable management of municipal solid waste in Nigeria. *Journal of Environmental Management*, 103(1), pp.9–14.
- 64 Agbo, C.O.A., 2011. Recycle materials potential of imported used vehicles in Nigeria. *Nigerian Journal of Technology*, 30(3), pp.118–29.
- 65 Egbu, A.U., Mbano-Pat, E.C. & Obialo, K.A., 2012. Public goods provision: Informal response to government failure in the cities of Nigeria. *Theoretical and Empirical Researches in Urban Management*, 7(2), pp.67–78.
- 66 Duminy, J., 2011. *Literature Survey: Informality and Planning* (Inclusive cities project). Massachusetts: WIEGO.
- 67 Nzeadibe, T.C., Anyadike, R.N.C. & Adama-Ajonye, O., 2012. *Informal recycling pattern, material linkages and urban governance in Nigeria*. Survival in the margins of African Cities: Informal Solid Waste Management in Nigeria [Workshop]. 21 August 2012. Abuja: Rockview Hotels.
- 68 Wilson, D.C., Araba, A.O., Chinwah, K., & Cheeseman, C.R., 2009. Building recycling rates through the informal sector. *Waste Management*, 29(2), pp.629–35.
- 69 Ibid.
- 70 Gerometta, J., Häussermann, H. & Longo G., 2005. Social innovation and civil society in urban governance: Strategies for an inclusive City. *Urban Studies*, 42(11), pp.2007–21.
- 71 Moulaert, F., Martinelli, F., Swyngedouw, E. & Gonzalez, S., 2005. Towards alternative model(s) of local innovation. *Urban Studies*, 42(11), pp.1969–90.
- 72 Ibid; Nzeadibe, T.C. & Anyadike, R.N.C., 2010.
- 73 Onyebueke, V. & Geyer, M., 2011. Informal Sector in urban Nigeria: Reflections from almost four Decades of Research. *Town and Regional Planning Journal*, 59, pp.68–80.
- 74 Ibid; Nzeadibe, T.C. & Anyadike, R.N.C., 2010.
- 75 Onyebueke, V. & Geyer, M., 2011.
- 76 Ibid; Oguntoyinbo, O.O., 2012.
- 77 Adebola, O.O., 2006. *New approaches of solid waste management in Lagos*. Solid waste, health and the Millennium Development Goals, CWG-WASH workshop. 1–5 February. Kolkata.
- 78 It is pertinent to note that the figure of 25 000 people recently cited as employed by the waste sector in Lagos comprises 2 000 LAWMA staff; 12 000 employees of Private Sector Service Providers (PSSPs); 8 000 street sweepers; 1 000 workers at the recycling facility and 2 000

- informal sector workers (Davids, B., 2009. Waste management is a lucrative business. The Nation Newspaper, [online] Available at: <http://thenationonlineng.net/web2/articles/9154/1/Waste-management-is-a-lucrative-business/Page1.html> [Accessed 27 May 2010]. However, recent research evidence has shown that the informal waste sector in Lagos constitutes an estimated 8 000 man workforce which consists of 3 000 pickers and 5 000 cart pushers (Adebola, O.O., 2006; Afon, A.O., 2007; Nzeadibe T.C. & Iwuoha, H.C., 2008).
- 79 Davids, B., 2009.
 - 80 Ibid; Nzeadibe, T.C. & Iwuoha, H.C., 2008.
 - 81 Ibid; Afon, A., 2012.
 - 82 Ibid; Nzeadibe, T.C. & Anyadike, R.N.C., 2012.
 - 83 Nzeadibe, T.C, Ayadiuno, R.U. & Akukwe, T.I., 2010. Solid waste governance in Owerri urban area, Nigeria: Problems and prospects. *Waste Management*, 30(2), pp.355–7.
 - 84 Ibid; Nzeadibe, T.C. & Anyadike, R.N.C., 2010.
 - 85 Ibid; Gerometta, J., Häussermann, H. & Longo G., 2005.
 - 86 Ibid; Nzeadibe, T.C. & Anyadike, R.N.C., 2010.
 - 87 Adepitan, A.O. 2012. *The Waste Collection Workers Welfare Initiative*. Paper presented at the international workshop Survival in the margins of African Cities: Informal Solid Waste Management in Nigeria. 21 August 2012. Abuja: Rockview Hotels.
 - 88 Forrest, K. & Tuwisana, K., 2012. Partnering to organise in Nigeria. *Waste Picking in Africa*, 2(1), p.10. Available at: http://globalrec.org/wp-content/uploads/2012/05/2012-04_newsletter-africa-english.pdf [Accessed 2 April 2013].
 - 89 Adepitan, A. Personal interview. 21 August and 12 November 2012. Adegboyega Adepitan is the Executive Director of the NGO.
 - 90 Sävström, J., 2012. All the work, but none of the credit. In J. Sävström (ed.), *Development Dilemmas: Annual Report 2012*. Uppsala: The Nordic Africa Institute.
 - 91 Nzeadibe, T.C. & Ajaero, C.K., 2010. Informal waste recycling and urban governance in Nigeria: Some experiences and policy implications. In J. Meijer & A. Der Berg (eds.), *Handbook of Environmental Policy*, pp.245–64. New York: Nova.
 - 92 Ibid; Forrest, K. & Tuwisana, K., 2012.
 - 93 Ibid.
 - 94 Ibid;., Nzeadibe, T.C. and Ajaero, C.K., 2011.

CHAPTER 6

Effective Integration of Scavengers in Solid Waste Recycling and Material Recovery

George Teke Forbid and Günter Busch

Concept, Role and Basis of Resource Recovery

The exploitation and use of natural resources to satisfy human needs continues to offer various global challenges, such as increased greenhouse gas emissions, lost resources and land degradation due to unsustainable lifestyles, waste disposal and deforestation.^{1,2,3} In addition, rapid population growth in Africa, coupled with a rural exodus, is creating high population densities around major cities, with the corresponding generation of enormous amounts of waste. High dependence on subsistence farming, with limited post-harvest processing of food crops, is a main cause of the large amounts of organic waste generated in most cities.⁴ Furthermore, dependence on imported new and used goods, which are always accompanied by various packaging materials, influences the waste quality.

Variations in municipal solid waste (MSW) quantity and quality depend on economic development, the lifestyle of a growing population, levels of industrial progress and existing waste-management systems.⁵ Amounts of resources recovered from MSW for re-use and recycling determine the effectiveness and sustainability of the management system.^{6,7} Effective resource management is fundamental to the sustainable social, economic and environmental performance and development of any community.

Resource Recovery: The Scavenging Approach, Method and Equipment

The resource-recovery scavenging approach (RESA) involves a purposeful, manual waste-sorting method that is developed and adapted to the situation in developing countries, with limited waste-treatment and application technologies. The method takes advantage of the rich, decaying, organic content of waste, as the biodegradable organic fraction is mainly composed of food, garden and post-harvest food crop residue, which can be composted to bio-fertilisers. At the outset, the waste sample is dried and spread out on a platform for sorting.

The recovery sequence continues thereafter, with the removal of bulky, risk-posing plastics, paper, metals and glass for recycling, while biodegradable organic particles, sand and soil residue are moved to the compost heap. It is recommended that additional scavengers are recruited, while training of existing scavengers should also be undertaken. Application of RESA requires basic tools, such as personal safety equipment for sorters (boots, dust masks, gloves, suits and goggles), along with wheelbarrows, spades, semi-automated sorting platforms, etc. However, depending on economic possibilities, automated and mechanised equipment, such as front-wheel loaders and sorting platforms with powered conveyor belts, could be used.

Application of RESA on Adapted Sorting Platforms

Scavengers form a community in informal solid waste management that plays an important role in the recycling activities involving waste-picking in the street, in temporary storage sites and at dump-sites. Unfortunately, scavenging is stigmatised and associated with high-risk, unhygienic environments, criminal activities, homelessness, unemployment, poverty, illiteracy and backwardness.^{8,9} This requires an understanding of the nature, cost, sorting principles and waste component end-usage. To apply RESA using an adapted sorting platform, the waste components and parts should be usable within communities, based on available technology, legislation and prevailing socio-economic constraints. This, for example, applies to metals, glass, high-calorific-value elements and biodegradable waste for recycling. Secondly, mixed-waste sorting, in order to obtain usable articles, considers particle dominance, size, and value. Thirdly, material recovery should minimise risk to the workforce and impact on the environment, i.e. risk-posing components are recovered first and treated with care.

Strengths and Limitations of the RESA

Table 6.1: Strength and limitations of RESA

Strengths	Limitations	Mitigation measure
Provides practical and affordable basis for integrated waste management.	Use of manpower with limited technology.	Automated technologies could be integrated at any point, depending on economic growth.
Makes use of modern and indigenous technologies.	Practice is new and requires initial capital.	Pilot plants could be created as education and awareness centres.
Creates jobs for skilled and unskilled labour.	Scavenging is stigmatised and socially downgraded.	Training and improved work conditions will change perceptions.

Opens opportunities for innovation and technology development.	Waste pre-treatment is influenced by seasonal variations.	Good planning, storage and use of mechanical biological treatment techniques will reduce impacts.
--	---	---

(Source: Author, December 2008)

RESA attempts to integrate modern and indigenous resources and technology that bridge the gap between theory and practice in resource-recovery from MSW. The concept of integrated waste management, sustainable resource utilisation and environmental protection has dominated contemporary environmental discourse in Africa, but with little practical application. Therefore RESA provides a practical starting-point for integrated waste management, though with certain strengths and limitations (Table 6.1). Since waste-sorting has pollution and resource potential, there is a need for proper control and monitoring of waste-handling and recycling practices, in order to minimise any impact on both the workforce and the environment.¹⁰

Waste Pre-Treatment and Component Characterisation

Due to significant differences between rainy and dry seasons in tropical countries, seasonal variations have a significant impact on waste quality, composition, and management. However, due to eco-living in most African cities, organic, biodegradable waste elements may vary quantitatively and qualitatively with the season. Hence collection and disposal of waste in landfills is influenced by seasonal changes, with mitigation measures presented in Table 6.2.

Table 6.2: Seasonal variables influencing waste management activities

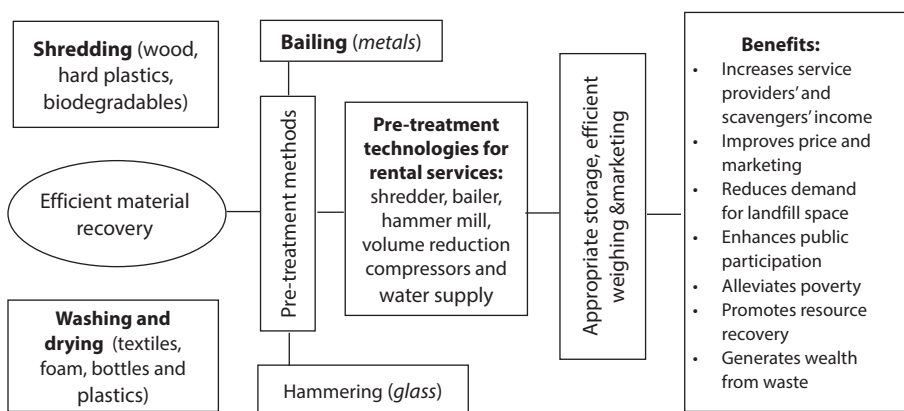
Characteristic variables		Season		Mitigation & improvement strategies
		Dry	Rainy	
Waste	Composition	Slight variation		Biannual waste analysis for five years in varied months and sources
	Weight	Low	High	Protect waste receptacles and bins from rain
	Digestion	High	Low	
Road network & transport	Prevalence of mud/dust	High dust	High mud	Repair roads in appropriate season
	Turnaround time	Short	Long	Effective landfill planning, with varied waste discharge platforms
	Spontaneous fires	Often	Rare	Enact strict fire-prevention rules

Scavenging activities	Recovery rates	High	Low	Use sheltered, multiple platforms to increase scavenging time and component recovery
	Hazardous waste	Common		Control sources of waste collected regularly, and sanction defaulters
	Regular health checks	Not regular		Sorters must have health checks bi-annually

Waste Pre-Treatment Principles, Technologies and Application

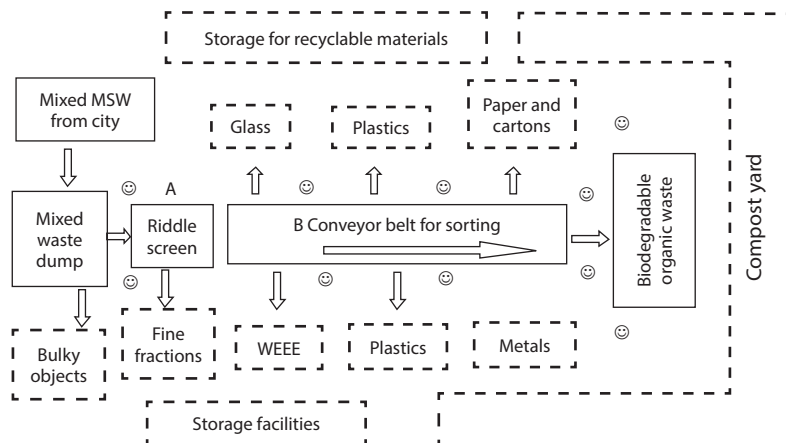
Waste pre-treatment can occur before and after sorting. Pre-treatment activities may include cleaning, compacting, pelletising, washing, weighing and transportation to market. Generally, scavengers only recover materials that have an acceptable market value. Hence, scavengers specialise in recovering different materials. As stated above, pre-treatment activities such as cleaning, pelletising and compacting are used, to add value and to deliver a corresponding increase in price. These processes may involve shredding, bailing, hammering, washing and drying (Figure 6.1).

Figure 6.1: Waste pre-treatment processes, technologies, and benefits



These pre-treatment technologies enhance scavenger activities by reducing volume and adding value to recovered materials. Currently, pre-treatment methods used to improve the quality of recovered materials include manual volume reduction by metal hammering, washing of foam materials and textiles, as well as the dismantling of waste electric and electronic equipment (WEEE). A RESA sorting-line, using appropriate technologies and human labour for sorting, could enhance scavenger activities, while boosting resource-recovery in the process.

Figure 6.2: Schematic plan for a RESA-based, mixed waste sorting line



Waste from the city is delivered to the dump-site where the sorting-line is located. The waste is sieved using a riddle screen (A) to remove fine particles of <60 mm diameter (rich in organic and mineral compounds) for direct composting, or anaerobically digested for bio-gas production (Figure 6.2). The coarse elements are then passed through a conveyor belt (B) and sorted manually, by suitably protected persons, to recover plastics and/or paper and cartons for energy recovery; metal, WEEE and glass for recycling; as well as the rest of the organic parts for composting.

Sources and Waste Component Properties

In most communities, waste disposed of at dump-sites comes from markets, residences, small and medium-size enterprises (SMEs) and commercial and general business areas. This explains the commingled nature of the waste. Since most council authorities are responsible for the collection and disposal of waste to dump-sites or landfills, scavenging occurs throughout the recovery process, from source to final disposal site. The representativeness of waste at the dump-site will therefore be different from that at source. Since waste-mixing begins at source and continues until disposal, pure waste collection, at the source of major waste streams for specific applications, should reduce entropy and sorting cost. For example, biodegradable waste from markets, restaurants and hotels, slaughterhouses and food-processing industries should be collected separately, at source, for use in bio-gas and composting plants.

Waste Sample Pre-Treatment and Analysis

During a waste analysis exercise carried out in Lagos, a representative waste sample was collected, weighed and dried under cover and in the open air, followed by

sorting and weighing of the major dry fractions recovered. It was found that effective, commingled waste-management should involve sorting to obtain recyclable elements for marketing to recyclers, with high-calorific waste used for energy recovery. Biodegradable waste can be composted and utilised as manure for farming, or anaerobically digested to obtain bio-gas for bio-energy and manure.

Waste Component Resource Analysis and Valorisation

Converting MSW (which is currently dumped and burned or landfilled) into recyclable and reusable resources with wealth-value, is fundamental to sustainable and efficient resource usage. Such a waste-to-wealth concept could motivate resource mining from existing and abandoned landfills and surface dump-sites. In addition, changing people's perception of waste, and empowering scavengers to recover valuable waste components, valorises waste as a resource. This is essential to achieving the landfill-elimination goal, creating jobs, alleviating poverty and improving community health and sanitation.

Current and Abandoned Landfill Utilisation

Most landfills in developing countries are not designed and constructed for the exclusive purpose of dumping waste. They are often abandoned parcels of land, previously used as quarries or laterite mining sites. Such sites sometimes offer significant natural advantages linked to the excavations, and surroundings are seldom inhabited, while rocky soil profiles prevent groundwater pollution. Using such terrain as a landfill site could provide short-term and long-term benefits. However, such sites are not common in most cities. The land recovered through waste landfilling, could be used as follows:

- A bio-gas production site is viable for energy-production over many years, provided the landfill is well covered.
- The landfill surface can be filled with soil (between one and two metres thick), with fruit and ornamental trees planted (afforestation). Greening such an environment sequesters carbon dioxide and accumulates bio-mass as a future source of fuel wood. The forest provides a habitat for varied biodiversity, and protects groundwater.
- The surface can be stabilised and used for the temporary construction of waste-sorting and recycling facilities.
- The landfill forms a stock of non-degrading material, which could be excavated for use over many years.

- Such abandoned landfills form research sites, with the potential to generate data on groundwater, soil and atmospheric impacts, including plant growth and biomass production rates.

Due to the composition of the wasteland filled, the landfills remain vulnerable to fire incidents and earth instability, especially when microbial biodegradation causes drying. While old landfills continue to provide the potential for material and energy recovery, the current sustainable waste-management paradigm advocates complete elimination of landfills in favour of waste reduction, recycling and re-use.

Changing Waste Perception and Empowering Scavengers

Appropriate education and awareness will change public and waste-worker perceptions, establishing a new waste-to-resource perspective. Such an educational programme should go beyond passive lectures, to the creation of small pilot projects that generate empirical data, supporting and proving how waste can be transformed into wealth. Although scavenging is an age-old practice that promotes resource-recovery and recycling from waste, scavengers remain stigmatised and socially downgraded. Most council authorities give little consideration to scavengers, who are sometimes chased off and/or victimised while sorting at waste dump-sites and landfills.

Establishing a resource-based management approach to waste-management requires that waste-management authorities rise above dependence on government funds to a sustainable, economically independent status. This requires a paradigm shift from providing hygiene and sanitation services to becoming a profitable environmental resource-management agency. Combining income from government subsidies, waste disposal fees and the marketing of recovered waste and energy will allow waste-management companies to become major economic players that offer excellent working conditions to all their workers. Table 6.3 presents strategies for improving waste-worker conditions, with positive potential impacts on waste services.

Table 6.3: Strategies for improving working conditions for waste workers

Work conditions	Improvement strategies
Job satisfaction and remuneration	Create multiple income sources with adequate workload and salary; recover and market resources from waste; provide work, equipment and safe working conditions for all workers.
Non-financial incentives	Provide equity in job appointments, basic toilet facilities, a comfortable working environment, health-care and insurance, job security and relevant staff development programmes.

Work duration and performance evaluation	Evaluate work quantity, quality and duration, including worker performance vis-à-vis wages paid, in order to prevent idleness, time-wasting and boredom at job site.
Skills, training and career advancement	Workers employed should have the potential to gain affordable skills, including on-the-job training and career growth opportunities.
Fair recruitment	Recruitment should consider job content, required worker skills and qualification, through a due process.

Waste Valorisation as a Functional Component of End-User Demand

In the consumer economies of developing countries, effective waste management should consider incentives for public participation. Table 6.4 provides a resource valuation of waste components after sorting in Lagos. Any waste component that can be sold or exported has material and thermal valorisation potential.¹¹ Since waste components are obtained free-of-charge by scavengers from dump-sites, the wealth value is equal to the labour employed during sorting and handling.

Table 6.4: Waste-to-wealth analysis for recovered waste components

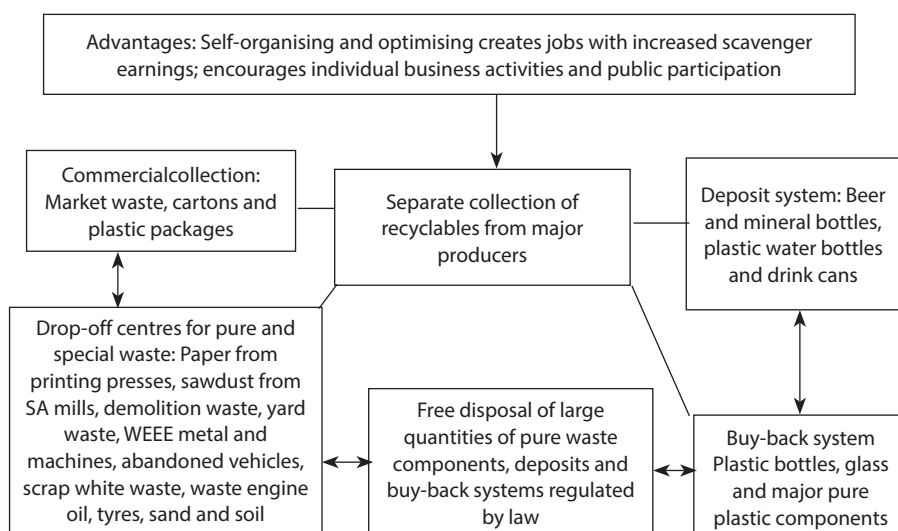
Waste fraction	Weight (kg)	Weight %	Local prices / kg	Main components	Remarks, value addition and utilisation potential
Residue material	45	26	None	Mainly organic, biodegradable, fine particles	Can be composted to bio- fertiliser
Sand and dust	22	12	Sand has a market value	Sand, soil and dust mixture	Sand from street-sweeping is recovered by winnowing or sieving
Plastics	35	20	De-pends on type	Lightweight packaging, medical drip-set bottles and water sachets	Recyclable: mechanically, to obtain secondary raw materials; or chemically, to obtain fuels and energy
Metals	2	1	De-pends on type	Cans, tins and cables	Recyclable locally or abroad
Paper and cartons	9	5	Varies	Newspapers, cartons and papers	Recyclable to toilet paper, or incinerated for energy production
Textile material	6	4	De-pends on state	Tailoring waste, used clothes, leather and shoes	Re-used for cleaning or combusted for energy production

Glass	1	1	De- pends on bottle type	Bottles and broken glass pieces	Recyclable locally, but unbroken bottles are re-used
Food remains	4	2	High com- post value	Foodstuffs and kitchen refuse	Digested for bio-gas production or composted to manure
Water	51	29	None	Water (evapo- rated)	Evaporates on drying

Implications of the Waste-to-Resource Analysis

Waste reduction minimises consumption of landfill space, and of necessity reduces collection, processing and transport costs.¹² Figure 6.3 presents a waste-reduction strategy that is based on separate collection of pure waste elements from source. This is underpinned by deposit, take-back and buy-back schemes for predominant waste components (plastic, wood and food waste, glass and bottles). Such schemes provide incentives for scavenging and public participation. Waste characterisation and the identification of major sources of waste are essential for designing and implementing a take-back system, locating kerbside centres for waste collection, and facilitating community involvement.

Figure 6.3: Modelling a community waste-reduction and collection system



Developing a New Waste-to-Wealth Paradigm for African Communities

Creating better waste-sector jobs with good working conditions is fundamental to changing current negative perceptions of waste-related jobs. Linking scavengers with improved output would help alleviate poverty, while at the same time achieving wider economic and social objectives.^{13,14} Some negative views attributed to waste jobs and strategies to overcome them include the following:

1. The low social status attached to unskilled and less prestigious jobs could be changed by instituting good working conditions, implementing on-the-job training, making waste-workers active agents of change and educating and empowering them to police and protect the environment.
2. Male worker dominance and gender bias could be changed by ensuring gender equity in the recruitment and promotion process, based on ability and qualification.
3. Low-educational-level jobs lacking skilled training and abilities could be changed by instituting an education loan scheme for waste-workers, thereby making working time flexible. Wages would be paid for work done, and at the same time create opportunities for part-time studies and motivation bonuses for new, acquired skills.
4. Employee contact with waste and contamination could be minimised by making use of obligatory safety and protective equipment to reduce health risks and change public perceptions.
5. Lack of intrinsic value attached to job quality could be improved by instituting a reasonable salary and other incentives to instil intrinsic value into waste jobs.
6. Multi-functioning of unskilled workers could be improved by establishing a waste workforce with a career-growth profile.

Waste Component Recycling

Since component recovering for recycling from mixed waste requires sorting, to reduce handling cost and negative impacts during collection, storage and transportation should consider these important factors:

- accessible bins at equitably-situated collection points, based on city mapping, with priority given to the shortest possible collection routes;
- that workers employed and skills required should correspond with available equipment and technology; and
- minimising turnaround time, including loading and off-loading, traffic congestion and frequency of trips, as well as distances covered and the number of vehicles available.

To minimise waste impacts on workers and the environment, waste pre-treatment and treatment should facilitate the recovery of the main components for recycling and energy production.^{15,16} Activities to enhance this process include:

- that mechanical and/or biological treatment should improve drying time, followed by spreading and sorting;
- identifying motivations and incentives for sorting, based on the potential application and sales of material and energy recovery; and
- that due attention should be given to cost-effective odour, noise and virtual impact control.

Determination of collection frequency, based on composition of waste and storage time, should consider weather conditions, settlement types, anthropogenic activities and population. These variables influence the utilisation of waste-collection vehicles, equipment and manpower deployment.

Effective Waste Handling

Effective waste-handling must consider any risks posed by MSW, depending on its source and composition. Waste-handling should prevent and control littering during collection, storage and disposal. Equitable distribution of protected waste receptacles minimises risk of theft, other damage and the impact of wind, rain and stray animals. Clearing of waste spillage from drainage tracks and removing the result of any illegal dumping will enhance a city's aesthetics, promote tourism and upgrade the socio-political status of the community.

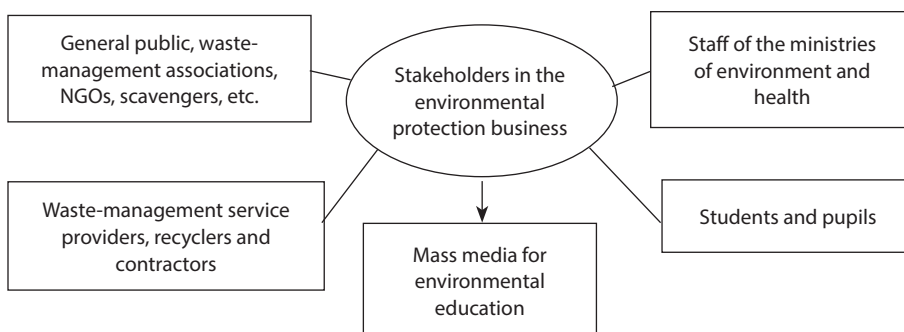
Waste workers should follow a strict hygiene, sanitation and safety code. Waste-management facilities, vehicles and equipment must be kept very clean. Although waste-handling should not take place in public, effectively-managed waste facilities should be open to visitors from all walks of life, as an exhibition of good waste-management practice. Such facilities should form training and education centres for the public, especially students and youths. Such good waste-handling practices will win the approval of residents, employees, service providers and government control agents.

Enhancing Public-Private Partnerships (PPP) in Recycling

Considering that environmental issues are still in the infant stage in most developing countries, education and awareness programmes are needed to establish good environmental governance. Waste-management authorities should showcase their successes, while using such opportunities to educate the public on the value of a healthy environment. Occasions that could be used to educate the public include

national and international celebrations, e.g. the observation of annual tree planting, world environmental and monthly environmental days. In addition, various radio, print and television programmes, including seminars, workshops and conferences, involving stakeholders in environmental protection business, should be organised (Figure 6.4).

Figure 6.4: Stakeholders in the environmental protection business



Improving Scavenging, Waste Recovery and Recycling

Scavenging of recyclable and reusable components occurs at landfills and along the waste-collection-to-disposal chain, which influences the amount of wasteland filled. Improving sorting and recovery of usable or recyclable material requires that waste-management authorities formalise, organise and enhance scavenging. Although scavenging could serve as a starting-point toward effective waste recovery, the integration of biodegradable organic waste and plastics, as well as more modern and appropriate energy-recovery technologies will boost small-scale, entrepreneurial resource-recovery activities.^{17,18,19,20}

Local end-users, as recyclers or consumers of recycled products from various recovered components, should be identified and motivated by local councils. Creating an incentive scheme to motivate scavengers and recyclers will advance efficient waste recovery. Non-financial incentive programs, such as free seminars and workshops on recycling, writing and presenting recognition letters to recyclers, offering competitive prizes and organising trade-fairs for exhibiting secondary products and services from waste-management, should also be employed. Organising scavengers and recyclers into mutually beneficial partnerships would enhance waste-component recovery and marketing, while boosting recycling.

Scavenger/Recycler Synergy

Organising scavengers and recyclers into co-operatives will facilitate the implementation of capacity-building and training programmes, while providing the opportunity for effective enforcement of health, safety and quality standards. The reinforcement of such standards can be facilitated by scavenger/recycler synergy. Local council authorities should serve as facilitators, supervisors and enforcers of the rule of law. Table 6.5 presents some scavenger characteristics, with improvement strategies and benefits for African cities.

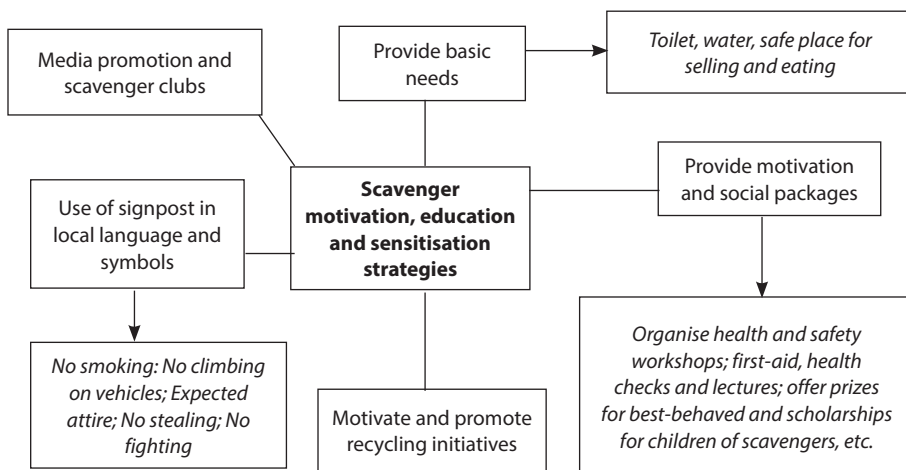
Table 6.5: Evaluation and improvement strategies for scavenging

Scavenger characteristics	Current situation	Improvement strategy and benefits
Role	Waste-reduction by sorting recyclables	Could sort all recyclables if given more time, with waste spread out to sell in improved markets
Organisation	Lacks an organisational body, with a leader	Enhance organisation, protect welfare, provide health checks and marketing of negotiations
Challenges	Work in rain or sun	Provide temporary shelter and protective storage for recovered recyclables to motivate scavenging
Activities	Sorting, storing and selling	Provide cleaning, baling and shredding facilities to improve quality, price and reduced transport cost
Motivation	Sale of recovered materials	Provide shelter, uniform and safety equipment to registered scavengers, who pay for such welfare services; create database of recovered materials
Waste components	Metal, glass, hard plastic, textiles, wood	Create enabling conditions to increase recovery; motivate recyclers; boost demand for recyclables
Regulations	Residence at dump-site is prohibited	Document and publicise regulations and charges governing landfill activities and infractions
Health & safety state	High risk exposure	Ban smoking, drinking, selling of food and eating around scavenging sites
Welfare	Lack of first-aid and health assistance	Provide basic emergency health care, regular health checks and risk assessment services
Recognition	Accepted and tolerated, but not recognised	Recognise scavengers as agents of recycling, waste and poverty reduction, and social change
Socio-economic value	Society of low-income earners	Establish enabling conditions and subsidies; offer scholarships to outstanding children of scavengers
Sustainability	Many scavengers scavenge for many years	Institute annual registrations, health checks and insurance, with personal information sheets within a scavenger database

Education and Implementation of the Rule of Law

Education and sensitisation on environmental, safety and health issues are fundamental instruments with which to change the status quo, maintain order around landfills and control scavenging activities. Although punishing recalcitrant scavengers may deter them from committing further offences, they still need to be educated on the existing laws: the reasons for their implementation and the benefits they will be entitled to for observing the laws. However, attention should be given to the heterogeneous nature of scavengers, often characterised by drug addicts, illiterate, handicapped and retarded persons. Some methods for educating, motivating and sensitising scavengers are shown in Figure 6.5.

Figure 6.5: Scavenger incentives, education and sensitisation strategies

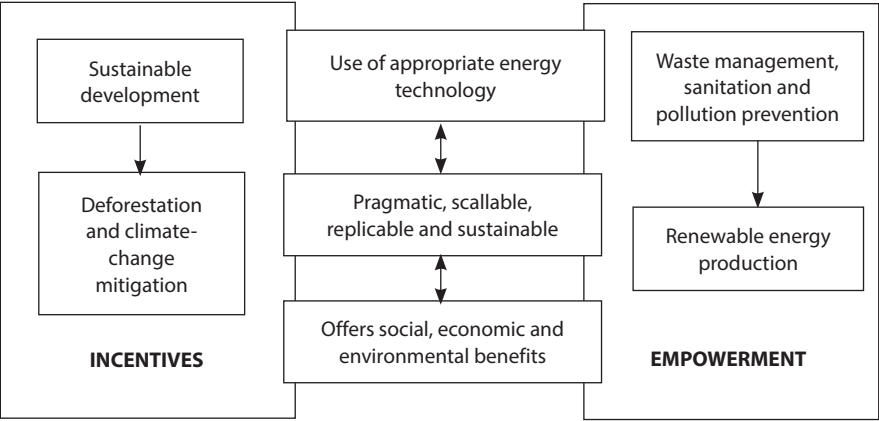


Safety, Hygiene and Health of Scavengers

As workers in a high-risk environment, who may become immune to some infections, scavengers may serve as carriers or transmitters of certain diseases. Hence, due to public health concerns, scavengers' health and safety behaviour should be of concern to waste-management and local council authorities. Basic principles of hygiene at scavenging yards, involving hand-washing, bathing and changing clothing after scavenging, should be strictly enforced. The creation of hygiene centres at waste-dumping and waste-recycling centres, if well managed, will serve the public and the workers at the waste-management facility at minimal cost.

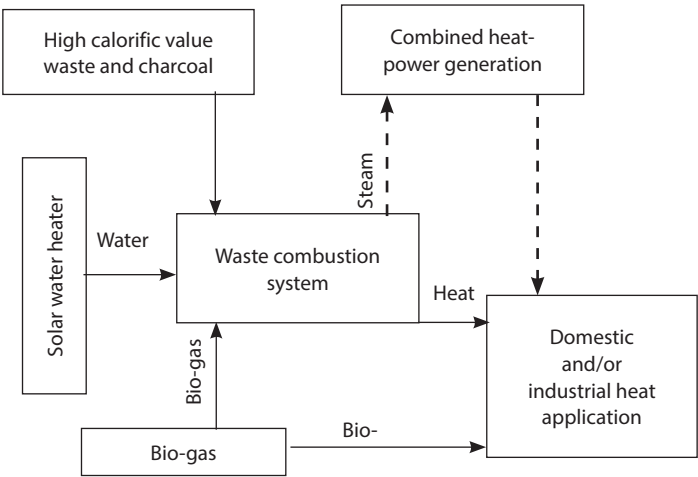
Role of Integrated Waste Management in Natural Resource Conservation

Figure 6.6: Using appropriate energy technology to improve waste management



Integrating renewable energy from solar, biomass and bio-gas within a waste-transformation and combustion system ensures reliable heat-power generation for domestic and industrial use (Figure 6.7). Energy and materials recovered from waste can empower poor city-dwellers, while improving health and sanitation.

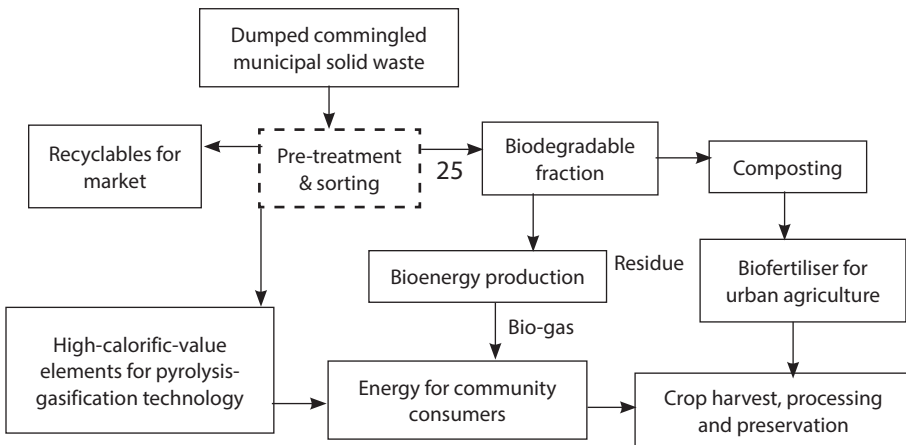
Figure 6.7: Integrated renewable energy production and utilisation mode



The Integrated Energy, Waste-Management and Agricultural Project

Effective sorting to recover recyclables (10–20 per cent) from highly disproportionate waste, dominated by biodegradable organic elements, should drive an economically and resourcefully-integrated energy, waste-management and agricultural system forward. The biodegradable waste can be composted to manure for improving farming, or anaerobically digested to obtain bio-gas and manure (Figure 6.8). Use of compost in agriculture would improve land-use systems and mitigate climate change.

Figure 6.8: Sustainable energy, waste management and agricultural project model



Trends and Perspectives on Integrated Waste Management in Africa

The African tropical climate provides ideal conditions for the growth of exotic plants, with attendant large biomass accumulations. However, with rapid population growth, the need for natural resources continues to rise. The need for agricultural products, such as food and wood for energy, requires improved farming techniques, with post-harvest processing and preservation that reduces the amount of organic waste disposed of in cities. This will concentrate pure post-harvest waste at source, with increased potential for recycling. It can be observed that all components of mixed waste have a potential use, with a market value. As the population will continue to rise, with corresponding waste-production rates, there is a need to increase resources recovered from waste. Waste-management firms could create pilot plants, in collaboration with research and development organisations. Such plants should integrate modern and appropriate technologies with the use of locally-available labour, in order to enhance alternative material and energy recovery, including recycling strategies and utilisation of waste.^{21,22}

Discussion

Waste-sorting is cost-intensive, energy-intensive, time-intensive and labour-intensive, whereas unskilled labour in most developing countries is abundant and relatively cheap. To improve workforce safety, any potential risks to manual sorting should be identified and mitigated. Enhancing and employing improved sorting techniques for recovering materials from mechanically bio-stabilised dry waste is cheap and affordable in developing countries. In addition, encouraging SMEs, engaged in recovery and usage of waste material, will increase the demand, market value and price of recovered products.²⁵ This should valorise waste and boost the recycling sector.

This waste-recovery and recycling approach is highly simplified in developing countries, so as to facilitate practical application, with stepwise improvement over time. Although the approach emphasises integration of human labour with indigenous and modern technologies in cost-effective pilot plants, the start-up point may vary, depending on the economic viability of the community. Starting and running an integrated waste-management, energy and agricultural project requires quantitative and qualitative waste-baseline data, which is essential for waste-management planning and training of scavengers to become waste-sorters.

Scavengers form a community in the informal solid waste-management sector that plays an important role in recycling activities, involving waste-picking in the street, from temporary storage sites and at dump-sites. Unfortunately, scavenging is associated with and stigmatised by high-risk, unhygienic environments, criminal activity, homelessness, unemployment, poverty, illiteracy, and backwardness. Formally integrating scavengers into waste-management practice could help to change this conviction. However, field studies conducted at landfills in Lagos, Nigeria indicate that some scavengers may be reluctant to work for a monthly salary. Consideration of scavengers' perception, motivation and desires is thus required, before integrating them into improved waste sorting programs.

Recommendations and Conclusion

The resource value of waste increases with purity, which implies that separate collection at source is the most recommended. However, separate collection is expensive, due to the many collection vehicles, receptacles, routes, logistics and the manpower involved. Most cities in developing countries lack these prerequisites to separate waste collection. However, effective waste management that promotes recovery and marketing of materials should involve sorting, with incentives for utilisation of secondary materials. Skilful manpower is required for managing waste and producing

appropriate waste-transformation technologies. Incorporating a waste-to-resource perspective in the human and urban development agenda of African cities involves:

- promulgating a shift toward recycling of recoverable materials to empower individuals economically – scavengers and green entrepreneurial initiatives;
- creating a competitive, vibrant, public-private sector partnership that is driven by social, environmental and economic benefits; and
- promoting sustainable waste-sector jobs, with business opportunities in the recovery, processing and marketing of secondary material and energy from waste, in order to alleviate poverty, while improving agriculture, food security and human welfare.

Targeted incentive sources for guaranteeing a cost-effective, integrated waste-management system include government subsidies, the sale of recovered items for re-use and recycling, compost as manure, bio-gas for energy production and waste-disposal charges. Cost-effective and integrated waste-management should motivate public participation, public-private partnerships and the marketing of recovered waste elements.²⁴

Notes and References

- 1 Foley, G., Kerkhof, P. & Madougou, D., 2002. A review of the rural firewood market strategy in West Africa (Working paper no. 35). Washington: World Bank.
- 2 Forbid, G.T., Fon, D.E. Busch, G. & Ajaga, N., 2011. A New Sustainable Waste Management Policy Approach that Optimises Environmental Protection. In E. Albrecht, T. O. Egute & G. T. Forbid (eds.), *Risk assessment and management for environmental protection in Sub-Saharan Africa*. Berlin: Lexion.
- 3 Guendehou, G.H.S., Koch, M., Hockstad, L., Pipatti, R. & Yamada, M., 2006. Incineration and open burning of waste. In IPCC (Ed.), *IPCC Guidelines for national greenhouse gas inventories* (Vol. 5). Kanagawa: IGES.
- 4 Tsi, E.A., Wiegler, G., Peschel, T. & Forbid, G.T., 2006. Socio-economic characteristics of a community forest in the western highlands of Cameroon: Case of Ijim Forest. *Global Journal of Agricultural Sciences*, 5(1), pp.5–10.
- 5 Forbid, G.T., Fon, D.E., Busch, G. & Frey, R., 2011. *Optimal valorisation of waste towards a cost-effective sustainable 'zero waste' practice: A waste-to-wealth approach of the Songhai Centre*. Proceedings of the 26th International Conference on Solid Waste Technology and Management. 27–30 March 2011. Philadelphia.
- 6 Giugliano, M., Cernuschi, S., Grosso, M. & Rigamonti, L., 2011. Material and energy recovery in integrated waste management systems: An evaluation based on lifecycle assessment. *Waste Management*, 31, pp.2092–2101.

- 7 Johannessen, L.M. & Boyer, G., 1999. Observations of solid waste landfills in developing countries: Africa, Asia, and Latin America. Washington: World Bank.
- 8 Wee, S.T., 2012. Socioeconomic of Scavenger: Study Case at Johore State, Malaysia. *Research on Humanities and Social Sciences*, 2(7), pp.91–97.
- 9 Nitivattananon, V. & Sembiring, E., 2010. Sustainable solid waste management toward an inclusive society: Integration of the informal sector. *Resources, Conservation and Recycling*, 54, pp.802–809.
- 10 Oteng-Ababio, M., 2012. When necessity begets ingenuity: e-waste scavenging as a livelihood strategy in Accra, Ghana. *African Studies Quarterly*, 13(1–2), pp.1–21. Available at: <http://www.africa.ufl.edu/asq/v13/v13i1-2a1.pdf> [Accessed 8 April 2013].
- 11 Biniecka, M., Campana, P. & Tarola, A.M., 2005. Thermo-valorisation in integrated waste management. *Microchemical Journal*, 79(1–2), pp.319–324.
- 12 Forbid, G.T., Ghogomu, J.N., Busch, G. & Frey, R., 2011. Open waste burning in Cameroonian cities: An environmental impact analysis. *The Environmentalist*, 31(3), pp.254–262.
- 13 Medina, M., 2000. Scavenger cooperatives in Asia and Latin America. *Resources, Conservation and Recycling*, 31, pp.51–69.
- 14 Fomba, E.M., Forbid, G.T. & Busch, G., 2011. Psychophysical determinants of waste sector workforce performance: Intergrating behavioural safety in risk management systems. In E. Albrecht, T.O. Egute & G. T. Forbid (eds.), *Risk assessment and management for environmental protection in Sub-Saharan Africa*. Berlin: Lexxion.
- 15 Hajekova, E., Spodova, L., Bajus, M. & Mlynkova, B., 2007. Separation and characterisation of products from thermal cracking of individual and mixed polyalkenes. *Chemical Papers*, 61(4), pp.262–270.
- 16 Hamerton, I., Emsley, A. & Azapagic, A., 2003. *Polymers, the environment and sustainable development*. England: John Wiley & Sons Ltd.
- 17 Huang, H. & Tang, L., 2007. Treatment of organic waste using thermal plasma technology. *Journal of Energy Conversion and Management*, 48(4), pp. 331–1337.
- 18 Jun'ichi, F. & Tomohiro, H., 2006. Measurement of the specific heat capacity of plastic waste/fly ash recycled composite using differential scanning calorimeter. *Japan Journal of Thermophysical Properties*, 20(4), pp.166–172.
- 19 Kasakura, T., Noda, R. & Hashiudo, K., 1999. Trends in waste plastics and recycling. *Journal of Material Cycles Waste Management*, 1, pp.33–37.
- 20 Lardinois, I. & Klundert, A.V.D., 1995. Plastic waste: Options for small-scale resource recovery (Urban solid waste series no. 2). Gouda: Waste consultants.
- 21 Consonni, S., Giugliano M. & Grosso, M., 2005. Alternative strategies for energy recovery from municipal solid waste Part A: Mass and energy balances. *Waste Management*, 25, pp.123–135.
- 22 Noda, R., Kamatzu, M., Sumi, E., & Kasakura, T., 2001. Evaluation of material recycling for plastics: Environmental aspects. *Journal of Material Cycles Waste Management*, 3, pp.118–125.
- 23 Bartone, C., Leith, L., Triche, T. & Schertanleid, R., 1991. Private sector participation in municipal solid waste service: experiences in Latin America. *Waste Management and Research*, 9, pp.495–509.
- 24 Zhang, G.H., Zhu, J.P. & Okuwaki, A., 2006. Prospects and current status of recycling of waste plastics and technology for converting them into oil in China. *Resources, Conservation and Recycling*, 50(3), pp.231–239.

CHAPTER 7

Solid Waste Management in Uganda: Challenges and Options

James Okot-Okumu

Introduction

Waste generation is an inevitable occurrence as societies endeavour to exist and develop within the different socio-economic clusters of the world. Although the term 'waste' may have different meanings for different people or communities, it is generally considered that waste is the 'unwanted' output or by-product of the person who discards it. It does not have value any more for the first user, and is therefore thrown away.¹ This definition, however, is considered subjective, since it does not incorporate the fact that waste could have value under different circumstances. Its usefulness can be derived from re-use, recycling and recovery or by conversion to beneficial necessities of life and socio-economic development, such as fuel (energy-bio-gas, electricity, heating, etc.), construction materials and handicrafts, and as a source of employment and income, depending on the characteristics of the waste in question.

It is, however, the negative attribute of waste that are causing much concern worldwide, because of the associated environmental, public health and aesthetic impacts. In the 1960s, waste management in African counties such as Uganda was efficient, because of lower urban populations and adequate resources.² This trend has, however, been reversed by the growing urban populations, caused by influx from rural areas, and resulting in enormous volumes of waste and increased demands on resources, budget and equipment.^{3,4}

Uganda, like most African countries, could not cope with the technology-intensive methods brought in from the developed world, and has experienced waste-management failures comparable to these African countries.^{5,6,7,8} It is also recognised that waste management in developing economies is often impeded by institutional, technical and financial constraints.^{9,10} Solid waste management problems exist along the whole management chain, from waste sources (generation) to final disposal or treatment. Waste-management problems are especially evident at the collection stage. Residents, particularly the poor, have to cope, at times, with weeks-old heaps of uncollected waste in their vicinity.

Poor solid waste management has direct and indirect impacts on natural resources, such as water and soil, and also on aesthetics. The problem, therefore, calls for a well-thought-out management system that is commensurate with demand. Waste management is one of the most visible urban services and is a very good indicator of the performance of urban authorities. It is known that MSW has a direct bearing on a city's attractiveness and its social, economic and political development.¹¹

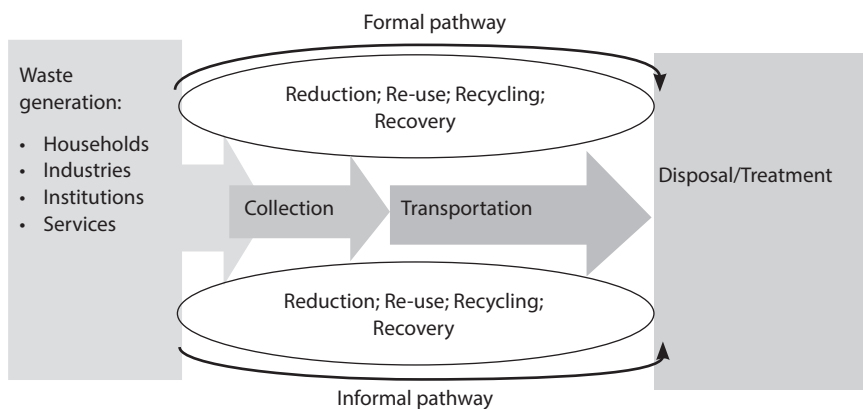
To illustrate the key issues of solid waste in the East African region, this chapter describes solid waste management in Uganda by considering the waste characteristics, management systems and challenges relating to the issue.

Solid Waste-Management System in Uganda

This section presents an analysis of the solid waste management system in Uganda, by describing waste generation and the waste management system in that country. It also provides information on stakeholder involvement in the management of solid waste. The first part is an overview of the existing solid waste management system, describing the different phases of management. The overview is followed by an analysis of the institutional framework for waste management in Uganda. The last part deals with waste characterisation and analysis of the waste-flow elements and stakeholder involvement.

Overview of Solid Waste Management

Solid waste management in Uganda consists of a sequence of activities that can be illustrated diagrammatically (Figure 7.1). These are the waste-management system elements with the integrated waste-management hierarchy elements of disposal, re-use, recycling and recovery. The main solid waste generation sources (by weight per cent) are households (including yards); service industries (markets, shops, malls, hotels and restaurants); institutions (schools, clubs, sports facilities, prisons); and healthcare (hospitals, clinics and drugstores).

Figure 7.1: Solid waste management system in Uganda

(Source: Author of this study)

Once generated, waste follows both formal and informal management systems, involving different stakeholders performing similar or different tasks. The waste can immediately be re-used, recycled or undergo recovery. In such circumstances, waste stops being regarded as waste, as it leaves the waste cycle at this point. The waste-reduction or minimisation strategies are applied in production by industrial manufacturers through the use of cleaner production (CP) techniques, which target waste at source by the elimination and minimisation of waste generation.

Waste can also be disposed of at source, causing undesirable impacts. Alternatively, waste can pass through the phases of the waste-management system until final disposal or treatment (Figure 7.1). These pathways are further elaborated upon in the section dealing with waste-management in this chapter.

The stakeholders (including waste-generators, the informal and formal sectors in waste management, policy-makers and financiers) all influence each of the stages of the waste-management system (WMS) and also interact, directly or indirectly impacting each other. Institutional arrangements for waste management are considered later in this chapter.

Waste-Generation Rates and Waste Characteristics

Waste-generation rates from municipalities are, on average, 0,55 kg/capita/day; with low-income locations at 0,3 /kg/capita/day and high-income locations at 0,66 kg/capita/day.¹² This is comparable to other African municipalities.^{13,14,15,16} The low-income urban communities have low purchasing power for marketed goods, and mainly buy foodstuffs that are, in most cases, consumed with little waste output. The major

quantities of food waste are from high-income homes, commercial locations (hotels, restaurants, eating places) and institutions (such as schools and clubs).

The total amount of solid waste generated by Ugandan municipalities varies, depending on each urban population. Substantial amounts of waste have to be dealt with by the urban authorities to maintain environmental and public health in these municipalities. The composition of solid waste from some selected urban centres in Uganda is presented in Table 7.1.

Table 7.1: Composition of solid waste generated by municipalities in Uganda

Composition (%)	Fort Portal	Jinja	Kabale	Kasese	Lira	Mbale	Mbarara	Mukono	Soroti	Kampala
Food	36,6	31,9	40,5	49,8	36,4	31,9	55,6	28,8	28,3	58,2
Garden	36,1	36,7	29,6	24,2	32,3	36,0	24,5	46,2	37,7	22,1
Paper	6,8	8,0	5,2	5,4	5,5	7,5	2,6	5,7	7,2	6,1
Plastic	8,4	7,9	8,1	5,1	6,8	10,8	4,7	7,9	8,8	7,2
Glass	0,7	0,7	0,5	0,4	1,9	0,9	0,6	0,4	0,7	0,7
Metals	0,0	0,5	0,5	0,1	2,2	1,0	0,2	0,3	0,4	0,3
Textile	1,0	1,8	1,8	0,5	1,2	1,0	0,3	0,4	2,5	1,8
Soil, ash, stones and debris	10,2	12,5	13,7	14,7	13,7	10,8	11,5	10,2	14,4	3,6
Others	9,8	9,0	10,1	13,4	12,2	7,7	9,9	8,4	11,1	2,6

(Source: Nema, 2007; Okot-Okumu & Nyenje, 2011; Okot-Okumu, 2012)

The average waste composition by weight (per cent) is: 37,7 food waste; 33,7 garden/yard waste; 6,0 paper and cardboard; 7,6 plastic; 0,8 glass; 0,6 metal; 1,2 textiles; 10,2 soil, ash, stones and debris; and 2,2 'other'.^{17,18} The biodegradable component of the MSW accounts for between 73 and 83 per cent (mainly food, and fruit and vegetable matter) of the total weight generated per day.¹⁹ Based on a study on the potential of municipal waste for composting, the quality of the waste is: pH range 5,7–6,9; moisture content 50–75 per cent; volatile solids 66–79 per cent; decomposable organic carbon 74–86 per cent; and volatiles from 66,2 to 84,1 per cent.²⁰

Evolution of Municipal Waste-Management Systems in Uganda

All East African municipalities practised centralised waste management for a long time, generally using imported refuse trucks to collect waste from the generating sources or community disposal points and transport them to designated disposal or treatment sites.^{21,22}

Similarly, the WMSs of Ugandan municipalities during the colonial days (the 1940s, 50s and early 60s) were totally centralised and efficient, because of the lower urban population and adequate resources already mentioned. However, after independence in 1962, the rapid increase in urban population, due to rural-to-urban migration, increased the amount of waste generated, over-stretching available management resources.^{23,24} This situation was also observed in Kenya and Tanzania, which clearly illustrates the common East African waste-management situation.^{25,26}

Solid waste management methods borrowed from developed economies often employ technology that is not directly relevant to African urban situations, because they fail to adequately consider local factors, such as waste characteristics, the climate, and human and technical capacity.²⁷

Urban councils (UCs) have often failed to provide adequate waste-management services, due to factors such as a lack of capacity to adequately adopt technology-intensive methods from developed countries. The waste-management problems have evoked various attempts to find solutions, mostly through institutional reform.

In 1997, Uganda adopted a decentralisation policy, realising that there was an incapacity to effectively deliver services to the different communities and environments of the country. The reforms were to strengthen local governments. They were initiated in the 1980s, and consolidated by the 1995 constitution that was further enhanced by the Local Government Act of 1997.²⁸

The centralised WMS has evolved into the current management approach, which includes decentralisation as well as the involvement of the private sector. However, with this evolving mode of management, waste storage, collection, transportation and final treatment/disposal are still seen as serious problems by municipalities.^{29,30}

Institutional Framework for Solid Waste Management in Uganda

Environmental management in Uganda was decentralised by the Local Government Act of 1997. The National Environment Management Authority (NEMA) is the body mandated to co-ordinate, monitor and supervise environmental management in Uganda (Environment Act, cap 153). NEMA is a semi-autonomous body that works closely with lead agencies (expert government institutions), non-governmental organisations (NGOs) and the public.

Solid waste management in Uganda is institutionally entrenched. This section describes how the existing institutional framework applies to waste management in Uganda. The operating policies, laws and financial mechanisms all act together to influence the way in which the waste-management system is shaped, and how stakeholders are involved. The policy and the legal and financial instruments are the core drivers that underpin the existing institutional systems for environmental management.

One of the main responsibilities of local governments is municipal solid waste management. When compared to other services, such as primary healthcare and road maintenance, institutional arrangements for waste management have not been clearly defined and are generally not prioritised. In most municipalities it is usually public health departments who are in charge of waste management. Some districts and municipalities have, however, recruited Environmental Officers, who are also involved in waste management. In most municipalities, Health Inspectors and Environmental Officers are not specifically trained to manage waste, yet they are the officials responsible for waste management. These officers are also not adequately facilitated (financial, transport, equipment, manpower) to efficiently carry out waste-management functions. The Ugandan waste-management challenges discussed here are a common occurrence in most urban African centres.^{31,32,33,34}

Waste-management systems can only operate well with strong national and local management instruments (policy, legal and financial). However, these management instruments do not operate in isolation, but reinforce or influence each other, and are also affected by external factors, such as the socio-demographic, economic and market dynamics of a country.³⁵

In Uganda, national policy-making is a core function of the central government, but implementation of policies and legislation is passed to the districts, which is in line with the decentralisation process that has been adopted by the country. The central government holds competence in the overall planning, coordination and supervision of legislation, which is the situation in all the East African Community (EAC) nations.

Environmental management functions, including waste management, are decentralised to local governments.³⁶ The decentralised institutional responsibilities for waste management in Uganda are summarised in Table 7.2, which illustrates the institutional framework and shows the key stakeholders involved in waste management in Uganda. To enable understanding of how the policy and laws are applied in waste management, this section explains the relevant policies and legal instruments.

Table 7.2: Institutional responsibilities for waste management in Uganda*

Management levels	Central Government (CG)	Higher Local Governments (HLGs)	Lower Local Governments (LLGs)
Institutional arrangement	Ministry of Water and Environment (overall responsibility) Other government ministries: NEMA (coordination and supervision) National committees	District councils/city councils (co-ordination and supervision at local government level); LC5 Municipality/town councils; LC4 sub-county/division councils; LC3 Technical committees Environment committees	Parish Committees Village Committees NGOs/CBOs Private companies Community
Responsibilities	Policy, regulations, monitoring Overall planning & coordination Supervision & quality assurance Capacity development	District, city, town plans Coordination and supervision of LLG Service delivery Support to community Monitoring and reporting to central government	Service delivery Participation in planning Monitoring and reporting to HLG
Statutory instrument	The Constitution of 1995 and the National Environment Management Policy (NEMP) of 1994. The overall goals, objectives and key principles for environment management in Uganda.	Key legislative documents for waste management in Uganda are: The Environment Act (Cap 153): waste-management modalities; pollution control; EIA The Public Health Act (Cap 281 of 2000): responsibilities in public health and sanitation The National Environment (waste-management) Regulations of 1999: regulates waste The Local Government Act of 1997: decentralised environmental management that devolves waste management to Local Governments The EIA Regulations of 1998 (Annex 3): EIA is mandatory for waste-management projects	

*Coordination, supervision and capacity-building are top-bottom, while reporting and information flow is from the bottom up.

(Source: Okot-Okumu and Nyenje, 2011)

The laws of Uganda elaborate roles and responsibilities at all levels of the national institutional arrangements to avoid the potential impacts of waste. The

Constitution of the Republic of Uganda (1995) is the cornerstone document of contemporary legislation in Uganda. The Constitution states in clause 39 that 'Every Ugandan has a right to a clean and healthy environment', while at the same time expecting citizens to play their part in creating a healthy environment: 'It is the duty of every citizen of Uganda to create and protect a clean and healthy environment' (clause 17).

The Environment Act (Cap 153) provides for all environmental regulations and standards, including sustainable waste management.³⁷ The main laws relevant to waste management include the National Environment Management Policy (NEMP) of 1994, which sets the key principles for environmental management in Uganda; and the National Environment (waste management) Regulations No. 52 of 1999, which outlines the duties and responsibilities of stakeholders in waste management. The NEMP (Section 3.9) sets the goal for control of pollution and the management of domestic and industrial waste.

Section 5 of the National Environment (waste management) Regulations S.I. No. 52/1999 provides for owners of facilities that generate waste to minimise the waste generated by adopting CP methods. The Regulations provide for identification and elimination of potentially negative impacts of the product/waste, and set out the requirements for licences for various different waste-management activities.

The over-arching aim of these laws is to ensure that every person has a right to a clean and healthy environment. The following sub-sections analyse how these laws are being applied in Ugandan municipalities.

In the international arena, Uganda has ratified the United Nations Framework Convention on Climate Change (UNFCCC). The country has thereby committed itself to combating greenhouse gas (GHG) emissions. In line with the UNFCCC, the Kyoto Protocol put in place a Clean Development Mechanism (CDM), as one of the mechanisms to allow developed and industrialised countries to invest in projects (in developing countries) that would realize GHG emission reductions.

As a show of commitment to the UNFCCC, Uganda submitted its Initial National Communication (INC) at the eighth Conference of Parties (COP) in 2002. Uganda is currently a non-annex1 (NA1) nation in the process of developing a national GHG inventory and mitigation system, and is preparing the Second National Communication (SNC), which illustrates the commitment of a NA1 nation in mitigating the impact of waste.

One of the ways in which Uganda has responded to mitigating the impact of waste is through the CDM, and by launching waste-composting projects in nine municipalities (Lira, Soroti, Mbale, Mukono, Jinja, Fort Portal, Kasese, Mbarara and Kabale) in 2005. The project was expanded to include eight more municipalities (Masindi, Busia, Hoima, Mityana, Entebbe, Arua, Gulu and Tororo) in 2010.

However, only three (Masindi, Hoima and Arua) of the latter eight municipalities had launched their schemes by 2012. The composting project's overall aim is reducing methane emissions from municipal solid waste, while at the same time producing manure for agriculture.

Indiscriminate waste-dumping in fragile areas, such as water-drainage channels (Figure 7.2),³⁸ wetlands and open water; infrequent waste collection and a lack of waste treatment all affect the environment and are potential health risks. These are indications that the waste-management laws are not being adequately followed by the population, and are not being effectively enforced by the authorities.

Figure 7.2: Drainage channels clogged with indiscriminately-dumped waste



(Source: Doreen Nakirya, for this study)

The adoption of waste minimisation and elimination practices is very limited, and practised mainly by the food and beverage industries through CP. Recovery by industries is likewise limited, and energy recovery is only common in the sugar industry, where *bagasse* is incinerated to generate electricity, some of which is sold to the national power grid. This is a positive contribution to the national energy requirements.

Although industries are obliged by law to treat waste in approved facilities, it is only the big manufacturing industries that have approved waste treatment facilities. The majority of industries engage in unapproved waste-management activities. Illegal dumping by waste- generators is rampant in all municipalities of Uganda (Figure 7.3), due to the inadequate public waste-collection system and, in some cases, avoiding the cost of waste-collection by waste generators.

Figure 7.3: Uncollected waste blocking part of a road and obscuring business premises



(Source: The author, 2008)

Another law still being applied to waste management is the traditional Public Health Law, which guides waste management and sanitation (Public Health Act, cap 281 – 2000). Traditionally the Public Health Act is enforced by the Health Departments of urban centres, which are mandated to implement waste management and sanitation in urban centres. The principal objective of the law is to keep the environment clean, improve aesthetics, safeguard and promote public health, and prevent the outbreak of disease.

Some municipalities have by-laws to control waste-dumping, and offenders are penalised. However, enforcement of waste-management penalties in most municipalities ranges from very weak to non-existent. Just as in many developing countries, indiscriminate waste dumping in Uganda continues unabated.

Financing Waste Management

The principal sources of funding for urban authorities are: central government; own locally-generated revenue; international development partners (through central government); and NGOs. These external sources of funding account for more than 70 per cent of the revenue of some local governments.³⁹

More than 85 per cent of the money transferred from central government to municipalities is in the form of conditional grants (tied to specific activities); which means the municipalities have discretionary powers over only about 10 per cent of the budget from central government.

Previously amounting to about 67 per cent of the local government's revenue, the Graduated Tax has been stopped, and this has had a huge impact on funding of local management activities.⁴⁰ Due to a lack of prioritisation during planning, waste management is poorly financed in all urban councils. The lack of prioritisation and budget restrictions

on funds from the national government means that, on average, Ugandan urban councils spend less than 10 per cent of their total funds on waste management.

Fiscal autonomy has not been realised by Ugandan municipalities. The national government does not adequately cost-evaluate the decentralised environmental management functions implemented by the urban councils. National priorities usually differ from Local realities, causing low remittances in these sectors by the central governments. The dilemma will remain unsolved for some time, because urban council local revenue sources are limited, and locally-raised revenues are, in some cases, as low as three per cent of total annual local authority budgets.^{41,42}

Disparities exist between municipal divisions or wards, because they generate different revenues on a local basis. It follows that those with higher revenues are able to provide better environmental services. Most of the money, however, is spent on drivers, turn-boys, labourers, fuel for vehicles and vehicle maintenance, and expenditure on actual or final waste disposal is very low.

The majority of the urban population in Uganda do not pay fees for waste services. However, between 34 and 56 per cent of the Ugandan urban population shows a willingness to pay for solid waste collection.⁴³ But this is among the predominantly low-income (poor) group, and is not in any way an indication of the ability to pay; it is, rather, recognition of the need for better environmental quality created by removing waste from their surroundings. Research has demonstrated that willingness to pay for waste collection is associated with income.⁴⁴ Econometric models can be used to test the association of willingness to pay for waste services with community socio-economic parameters.

Elements of Solid Waste-Management in Uganda

This section describes in detail the elements of solid waste-management systems operating in Uganda, from the waste-generating sources through collection and transport to final disposal and treatment (Figure 7.1). The waste-management phases and the activities in each of these phases that include the elements of waste management are described in detail in the following sections.

Urban Solid Waste

There are various urban consumption and processing activities which, on a day-to-day basis, produce waste of different kinds, with solid waste prominent among them. The accumulated waste materials are items no longer desirable to the generators, usually of no use to them, and therefore disposed of. This waste is, in most cases, unsorted (Figure 7.4) and stored on-site in various categories, depending on the generators (Figure 7.5).

Figure 7.4: Indiscriminate disposal of unsorted waste in Kampala suburbs: (A) & (B) waste at Kawempe market and (C) waste at Luzira residential area



(A)



(B)



(C)

(Source: Doreen Nakirya, for this study)

Figure 7.5: Domestic waste storage bins used by affluent households and sacks used by poor households



(Source: The author, this study)

The generated municipal waste characteristics are described earlier in this section and Table 7.1. The waste consists predominantly of decomposable organic materials. An emerging type of waste in Uganda is electronic waste, or 'e-waste'. There is no comprehensive data on electronic waste available for Ugandan municipalities, even though it now forms a significant component of disposed waste, in terms of risk to the environment. A study in 2008, however, indicated that 2 000 tons of e-waste was generated in Uganda in 2007, mainly from computers and associated equipment.⁴⁵ There is no formal e-waste-management system in Uganda as yet, and formal recyclers do not exist. However, a policy for managing e-waste for Uganda was drafted in 2010.⁴⁶

The highest waste-generators in Uganda are homes and markets, which, proportionally, are also the source of the largest amount of decomposable organic waste. By the year 2006, Ugandan municipalities were already generating between 87,7 and 645,05 tons of waste daily.

Using the population projection (Equation 7.1) and base year of 2006, the total amount of waste generated by Ugandan municipalities was calculated (see Table 7.1), and amounted to 1947 tonnes/day for the year 2013, with a projection of 2091 tonnes/day for the year 2016 (Equation 7.2).⁴⁷

Equation 7.1: Population projection

$$\text{Projected Population} = P (1+r)^n$$

Where: P = population in 2006; r = 0,024; and n = the number of years since 2006.

Equation 7.2: Projected waste tonnage per day for the year 2016

Waste generated per day = the product of the projected population and the national per capita waste-generation per day = $(P \times 0.55\text{kg/cap/day})$

The calculated daily waste generation rate is then used to calculate the annual waste production rate, which is the recognised format of reporting by IPCC 1996.

Equation 7.3: Methane-emission potential

Calculation of methane emission potential was based on IPCC 1996, adapted from NEMA.⁴⁸

$$\text{CH}_4 (\text{Gg/yr}) = (\text{MSW}_T \times \text{MSW}_F) \times \text{MCF} \times \text{DOC} \times \text{DOC}_F \times F \times (16/12-R) \times (1- \text{OX})$$

Where:

1 Gg/yr = 1 000 tonnes/yr

MSW_T = total municipal solid waste generated (Gg/yr)

MSW_F = fraction of MSW disposed of at landfills (FDS)

MCF = methane correction factor (fraction); default 0,8 adopted for Kampala

DOC = degradable organic carbon (fraction)

DOC_F = fraction of DOC dissimilated

F = fraction by volume of CH_4 in Landfill gas (LFG; default is 0,5)

R = recovered methane (Gg/yr) = 0 for Uganda; no methane is collected

OX = oxidation factor (default is 0)

Equation 7.3 gives estimates of methane-emission potential as being between 0,9 and 4,12 Gg/yr. total = 18,52 Gg/yr (Year 2006) for nine towns in Uganda. These estimates are, however, crude because of a lack of comprehensive data on solid waste in Uganda.

The total methane (CH_4) equivalent generated per day, based on projected waste-generation rates, is: 24,2 for the year 2013; and 26,04 for the nine towns in the year 2016. This is based on the **assumption that the waste-management status quo is maintained.**

In the larger municipalities and cities, commercial areas are expanding and the ratio of contribution to the waste stream is increasing relative to the domestic generators.

Table 7.3: Contributions to the waste stream by generators

Solid waste streams	Contribution in weight %	Waste characteristics	Comments
Domestic	52	Major: food waste and yard waste Minor: paper; plastic; textiles; glass; ceramics; ashes; leather; compound waste	Quantity increasing with population - Waste collection: urban councils; private companies
Markets*	20	Major: vegetable waste (leaves, stalks), spoiled fruit Minor: damaged packaging materials (e.g., sacks, bags, paper, timber)	- Markets in all municipalities - number increasing - waste collection: urban councils
Commercial (excluding markets)	8	Major: packaging materials; food waste; scrap metals Minor: glass, hazardous waste (e.g. contaminated containers, batteries and cleaning textiles)	Shops, hotels, restaurants, offices, open pavement trading - mobile open-air traders - increasing business - increasing waste volumes - waste collection: urban council; private companies
Institutional (e.g. educational, sports facilities, clubs)	5	Major: food waste, stationery Minor: packaging (e.g., cardboard, paper, plastics)	Expanding in numbers with population increase - waste collection: mainly private companies

Industrial (manuf- turing)	3	Various types de- pending on industry (e.g. decomposable waste from food industries; non-degradable, such as broken bottles and plastic containers)	- broken bottles: no recycling plant in Uganda - plastic: recovered, re-used, recycled - Recycling plants in Kampala
Healthcare (hospitals, clinics, drug shops)	1	Domestic type of waste dominates by weight; hazardous waste are significant	Major hospitals treat own hazardous waste. High-risk waste - clinics dump with other waste
	11	Examples: street-sweepings, public park waste, construction waste	collected by: urban council and private companies

*Merchandise for urban markets comes with enormous amounts of waste (e.g. leaves, stalks, grass, sacks, and branches) from the countryside.
(Source: Okot-Okumu, 2012)

Waste generators have begun practising elements of the waste-management hierarchy by becoming involved in prevention/minimisation, recovery, recycling and/or re-use.

Waste Collection and Transport Services

Waste-collection in all municipalities of Uganda has evolved from the purely centralised systems provided by the urban authorities to the current combination of systems. Collection of waste is done by the formal and informal sectors to varying degrees, depending on the waste sources. Waste collection is between 15 and 60 per cent (average about 40 per cent) of the waste generated. However the collection efforts apply only to waste that have reached community transfer points, such as skips, bunkers and of course illegal disposal of waste on open ground.

In all municipalities, the highest collection levels are in urban zones served by private companies. Densely-populated areas with poor communities receive the lowest waste-collection services, or none at all. In such localities (e.g. slums), waste collection is hampered by the lack of access roads and an inability on the part of communities to pay for collection services, similar to the situation in other developing countries.^{49,50}

The house-to-house waste-collection scheme, collection from business premises and institutions, and co-operation between industries comprises the formal collection. The informal collection involves members of the community and some

individuals employed by the formal sectors who pick valuable waste, store it in sacks and sell it to middlemen.

The informal waste-collectors play substantial roles in waste management, especially at the first stage of collection from the poorer households to community transfer points. In Kampala, 21 per cent of households are served by informal waste collectors; the rest are served by Kampala Capital City Authority (KCCA) (12 per cent), the formal private sector (44 per cent), Community-based organisations (CBOs) (one per cent) and themselves (22 per cent). Municipal authorities collect waste mainly from markets, public places (business centres), community transfer points (skips, bunkers, open-road verges), some households, or by 'hoot and pick' at agreed locations.

The informal sector forms the core of itinerant waste collectors who are involved in the recycling and re-use business, especially of plastics, glass bottles and scrap metals (Figure 7.6).

Figure 7.6: An itinerant plastic waste-collector transporting his waste to a middleman in a Kampala suburb (arrow points at waste bag)



(Source: Author, this study)

Collectors pick up waste from homes (usually in waste-bags), community transfer points (skips and bunkers) and unofficial dumps (e.g. road verges). In Ugandan municipalities, uncollected waste is treated by the community in different ways, including indiscriminate disposal (58,7 per cent), designated area disposal (15,5 per cent), back-yard disposal (10,1 per cent) and other methods (15,7 per cent), which include burying, burning, feeding to livestock and home-composting.^{51,52}

Informal waste collectors are not under any form of control, and therefore employ very simple technologies (bicycles, wheelbarrows and physical heaving) and dispose of waste in the nearest open lot (unofficial points). Indiscriminate disposal

of uncollected waste is common in all municipalities (Figures 7.4 and 7.7). Therefore, even though they provide services to households at low cost, the overall benefit to the community as a whole is negatively affected by ongoing environmental pollution.

Figure 7.7: Illegal dumping of waste on road verges



(Source: Author, this study)

Commercial operators in most municipalities do not have separate waste-disposal containers, and put their waste in the most convenient place close to the premises where they are collected. They sometimes hire informal waste-collectors to deliver it to nearby designated disposal points. Restaurants and hotels, in most cases, are handling their own waste – either through contracted service providers or farmers, who collect food waste to feed their livestock. Most manufacturing industries are served by private waste-collectors, who pick up waste from on-site containers and deliver it to official disposal sites.

Some industries exchange waste, where waste from one industry is a raw material for the other. For example food-processing industries (fish and meat processing) and abattoirs are sources of raw materials for the animal feed industry. Coffee-husks and rice-husks are useful sources of fuel for industries such as cement, brick-making and tile-making.⁵³ This is a good way of waste minimisation at source, which is being taken up by many food processing industries in Uganda.

Formal waste collection is done by the Town Councils, using motorised mechanisms. The bigger towns (municipalities and cities) have better financing, which allows them to have a better-organised waste collection system. This is now evident in Kampala City. Private waste collectors also use motorised collection to retrieve waste from paying customers. Waste collection is tightly linked to waste transportation, which is discussed later in this chapter.

The most common community collection/transfer facilities are skips (usually 5 and 6 m³, but sometimes 10, 15 and 20 m³) and bunkers (three sides, with an open roof), which are inadequate in all urban areas of Uganda. In many municipalities, skips attract enormous amounts of waste and are overwhelmed when waste collection is irregular. These collection/transfer (skips, bunkers or open grounds) points are therefore

often overflowing with uncollected waste, with consequent impacts on the community (environment, public health, aesthetics) and the environment. These waste points are often situated along the main roads, next to markets and in most commercial areas accessible to waste-collectors' transport mechanisms. Collection from other locations varies in frequency from none at all to three times a week. As a result, the waste often rots on site and ends up leaching into the environment, or is scattered by animals and the wind (e.g. paper and plastic bags). When it rains, the waste is washed into drainage channels, clogging them and causing flooding (Figure 7.2).

Though illegal, dumping along roadside verges is very common in all municipalities. Although penalties exist for such activities, they are rarely enforced. Municipal councils continuously collect waste from such illegal dumps. The most common collection frequency among waste-collectors is twice a week, whereas the informal sector and private companies collect waste at frequencies comparable to those of the public sector.⁵⁴

Hazardous waste, which comes mainly from health facilities, some industries, petrol stations and pharmacies, are collected by licensed companies that are authorised to handle the waste categories. Hazardous waste is often incinerated to avoid re-entry into the environment.

It is argued that if the waste management systems were more efficient, they could help give rise to more small-scale waste collection services, which may prove to be a cost-effective combination. A point in case is Kampala city, which has improved its waste-collection services, and this has caused a reduction in the number of indiscriminate, proliferating neighbourhood disposal points.

The transportation of waste can also be divided into formal and informal modes. The formal transport is organised by the municipal or town councils, and by private companies licensed and under contract to the municipalities to deliver waste to gazetted disposal or treatment points. Informal transport is organised by individuals hired by waste-generators, individuals handling their own waste, and itinerants. The informal transport delivers waste to community transfer points, pits or other places, such as illegal sites, in order to somehow get rid of the waste from the generation points.

Waste-transport vehicles include compressor trucks, skip carriers, open trucks and the tractor trailers that are common to both the public (municipalities) and private (licensed companies) waste transporters. In all cases, the waste is loaded onto the trucks manually by hired workers, who in most cases lack the appropriate tools and personal protection gear. Formal waste-collectors deliver waste to gazetted disposal sites or treatment points (compost plants, energy recovery).

The amount of money paid by households to private waste-collectors is between US\$2,80 and US\$22,70 per month. The public collectors (municipalities) charge

between US\$8,00 and US\$14,40 per month, and the informal sector charges between US\$1,00 and US\$5,70 per month. It is simply not possible to achieve optimal collection and transport of waste, because of lack of adequate funds municipal funds, the poor road network and high fuel costs. Both the private and public collectors and transporters have inadequate waste trucks, equipment and manpower. In the smaller towns, there are periods when there is no waste collection or transport at all, because of broken-down waste trucks and lack of funds for repair. The unreliable waste-collection and transport makes the whole waste-management system in the municipalities inefficient.

Formal waste-collection has, however, greatly improved since the 1980s, when coverage was below 20 per cent, to the current level of between 16 and 60 per cent. With better planning and better allocation of resources, collection coverage could be greatly improved.

Waste-Treatment and Disposal

When waste is collected, it is transported to locations where it is, in one way or another, treated and/or disposed of. Formal waste-disposal in Uganda involves land-fill (only in Kampala) and gazetted waste-disposal points, while formal treatment includes composting and energy recovery.

As already stated, the CDM project was initiated in nine municipalities in 2005, and the planned expansion to eight more municipalities resulted in the launch of the project in three towns during 2012. These are voluntary (NEMA and municipalities) projects funded by the World Bank. It is estimated that the aggregate emission reduction by the first nine of the CDM projects together has totalled approximately 900 000 Emission Reductions (ER's) over a period of 10 years.⁵⁵ International Finance Corporation (IFC) stated that: *A total of 156 889 Certified Emission Reductions (CERs) and 52 296 Verified Emission Reductions (VERs) will be sold to the Community Development Carbon Fund (CDCF), and include additional funding to implement a Community Benefits Plan. The entire programme is voluntary in nature, both for the National Environment Management Authority (NEMA) and the municipalities.*

Waste is delivered by truck to the compost plants, but as there are no weigh-bridges, it is not possible to record the amounts delivered daily. The projects were, however, designed with an optimal capacity of 70 tons/day, but most of them often operate at full capacity because of the collection and transport problems already discussed in this chapter.

The composting process takes about 52 days, during which the organic fraction of the waste undergoes several phases of conversion into compost. Repeated sorting takes place on the final product to remove the remaining inorganic fraction. The

composting process is monitored, and the data used by NEMA and the World Bank to calculate methane and CO₂ emissions, on the basis of which carbon credits are granted to the municipalities.

Another formal waste treatment method is energy recovery from waste to provide fuel to generate electricity. It is a method commonly used by sugar factories, where *bagasse* is burnt at a high temperature to produce steam, which in turn drives turbines to produce electricity, which is used by the factories, with any surplus being sold to the national grid. Rice-hullers and coffee-hullers, commonly found in the outskirts or within towns, sell the husks (waste) to factories that require heating fuel, such as for cement-making and brick-making.

Organic waste fractions, such as coffee and rice husks, are also being used to make briquettes for use in energy-saving stoves. These waste-recovery practices are of significant importance as a waste reduction strategy.

Informal waste treatment activities are various, and can be identified as those serving to get rid of waste from generators, and those regarding waste as a resource. The informal treatment methods are in response to waste-collection shortcomings, where waste is not collected. The waste-generators therefore resort to their own solutions, and some members of the communities take the opportunity to earn an income by deriving value from the waste.

Waste-Management Challenges

Based on the national legal provisions, municipalities in Uganda are responsible for the management of all waste produced within their boundaries. Some of these municipalities have their own ordinances to implement waste management according to their individual situations. However, in most municipalities, the national waste-management laws and ordinances are not effectively implemented. The informal sector and the community therefore operate with little or no regulation at all.

Another crucial issue is that waste management is poorly financed in all the municipalities, because it is not an activity prioritised by all the urban councils. Funds for the operation of the urban councils come mainly from external sources. 'The central governments do not adequately cost-evaluate the decentralised environmental management functions implemented by the urban council', because national priorities usually differ from local municipal environmental management activities. Studies in the East African region clearly illustrate the financing dilemma relating to the management of solid waste.⁵⁶

The main problems associated with waste management can be categorised as fiscal (lack of funding), socio-cultural (lack of awareness, education, attitude) and technical (capacity, wrong equipment, inadequate equipment). The communities

largely perceive waste as a problem, and something that should be the responsibility of the Authority.

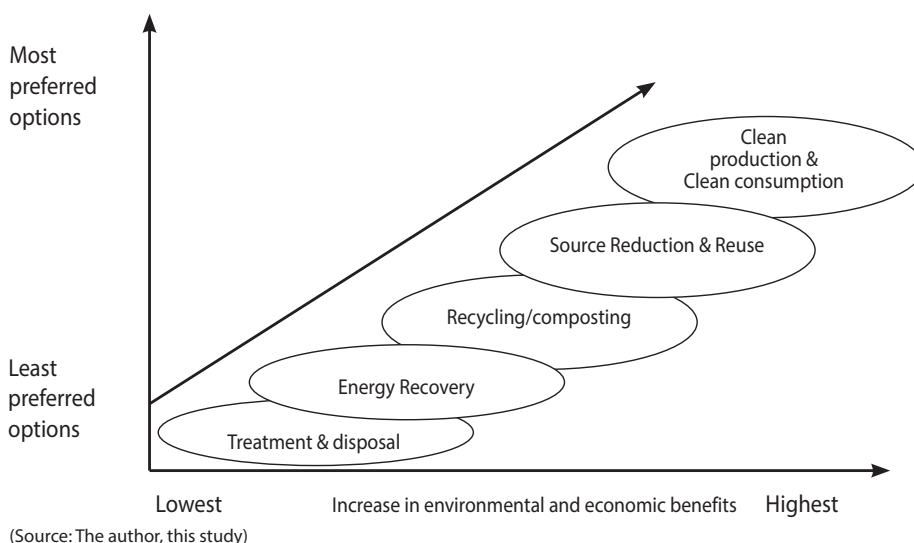
Other waste-management problems mentioned by the Kampala community are: infrequent waste collection (54,3 per cent); skips and bunkers too far from generation points (18,8 per cent); indiscriminate waste-disposal (20,2 per cent); lack of designated waste-disposal points (2,1 per cent); and 'others' (4,6 per cent).

The challenge of solid waste management can be addressed collectively by looking at new approaches that include both the traditional centralised town council-based approach and new decentralised-community based approaches, to create a mix that best fits the particular town council and its inhabitants.

Innovative Waste-Management Efforts in Municipalities

This section describes ways in which waste is considered a resource rather than a problem. Some of these methods of waste-handling have already been mentioned in the earlier sections of this chapter. The description here dwells on waste-management hierarchy elements that, to some extent, have been adopted by municipalities and the urban community. These elements are waste prevention/reduction, re-use, recycling and recovery (Figure 7.8).

Figure 7.8: Waste-management hierarchy



In this section, the waste-management hierarchy elements are defined as those used for the implementation of integrated sustainable waste management (ISWM)

activities.⁵⁷ As one moves up the ladder in Figure 7.8, the management practices become more environmentally acceptable, economically viable and sustainable.

The ISWM model describes the involvement of the various stakeholders (local authorities, NGOs/CBOs, service users, the private informal sector, private formal sector and donor agencies) in a reinforcing manner in solid waste management. The ISWM concept identifies six aspects (technical, environmental, financial/economic, socio-cultural, institutional and policy, legal and/or political) through which an existing waste system can be assessed, and with which a new or expanded system can be planned. The main aim of the ISWM model is to achieve sustainability of the management system, as illustrated in Figure 7.8.

Waste Prevention/Reduction

Waste prevention/reduction can be considered as the creation of mechanisms to prevent waste in product design, packaging and use, and/or reducing the toxicity or negative impacts of waste generated. At household level, this is usually done through various activities that lead to the extension of a product's lifetime. For example, the use of items for a longer time includes repairs to extend the lifespan and re-using of the product for similar or different purposes.

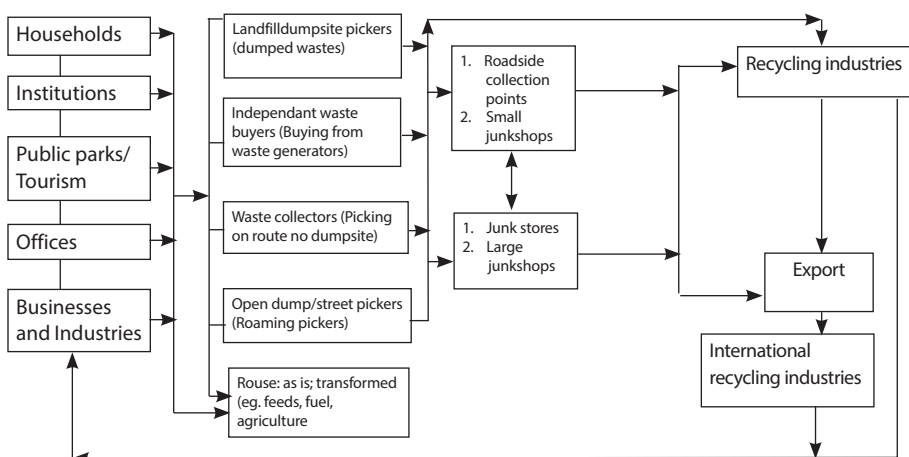
At industry level, prevention and reduction involves the adoption of CP practices, which consider the whole life-cycle of a product, thereby preventing or minimising waste with accruing benefits. Waste-prevention and reduction takes place at all phases of the waste-management system, where the lifespan of used products is increased when items are retrieved by the community and waste-workers for further use. This mode of management has been considered earlier in this chapter.

Re-Use of Waste

This is considered as the re-use (in their current form) of materials or products retrieved at the different phases of the waste stream. These are items such as bottles, cups, plates, basins, plastic bags, items of clothing and household items, including elements of furniture and equipment that can be re-used in an unchanged state. In Uganda, such items are either sold at open markets or by itinerants, who bring the items directly to prospective buyers. The traded items are either obtained locally, or imported into the country as used goods.

Recycling of Solid Waste

This element of the waste-management hierarchy involves the conversion of materials for use as direct or indirect inputs into new products. This element of the waste hierarchy is illustrated in the waste-recycling chain graphic (Figure 7.9).

Figure 7.9: The waste-recycling system in Uganda.

(Source: The author, this study)

Materials recovered along the waste streams are processed into products, materials or substances for either the original, or other uses. This does not include energy recovery, fuel or backfilling operations. Materials retrieved by Ugandan urban communities for recycling include plastic (Figure 7.10), metal, paper, organic waste (composting) and industrial waste (bones and offcuts). Some of these materials (e.g. plastic) are recycled by local industries within Uganda, while others (e.g. cardboard) are predominantly exported for recycling. Figure 7.11 illustrates some products of recycling common in Uganda.

Figure 7.10: Waste plastics being sorted at Kiteezi in Kampala for weighing and sale to recyclers

(Source: Doreen Nakirya, for this study)

Figure 7.9 illustrates how recyclables are sorted out of the waste stream. The waste sources (households, public/private institutions, public parks, offices, businesses and industries) generate the recyclables from their solid waste. The recyclables are picked out of the waste from source, community collection/transfer points (skips, bunkers or open dumps), en-route to the disposal sites/landfill, or at the disposal site/landfill itself. The picked recyclables are sold to middlemen (collection-points or junkshops), who in turn sell them to recycling industries locally.

As can be seen in Figure 7.9, the informal sector plays a dominant role in the picking of materials from waste for recycling. This activity, apart from providing a means of income to some members of the urban community (waste-pickers), also subsidises the income of waste-workers who pick recyclables as they load, transport and offload waste trucks.

Figure 7.11: Aluminium pan (left) and charcoal stove (right) made from recycled metal



(Source: The author, this study)

The waste-pickers/sorters sell plastic at US\$0,10 per kilogram to middlemen, who in turn sell it to the recycling industries at about US\$0,30 per kilogram. Scrap metal is bought at about US\$0,10 per kilogram and sold to recycling industries at about US\$0,35 per kilogram. These prices are not fixed or controlled, but negotiated between the sellers and buyers. Local artisans also practice recycling of these materials, which are sometimes obtained through their own pickings at no cost.

Recovery

The main recovery activities are energy from incineration (for industries), briquettes (for households – see Figure 7.12), and anaerobic digestion (bio-gas). The formal recovery process common to most municipalities is the CDM composting project, with carbon credits, as presented earlier in this chapter. Briquettes are made by some small-scale industries and community groups. Figure 7.12 illustrates one of the most promoted briquette types in Uganda, which is sold together with an energy-saving briquette stove.

Figure 7.12: Briquettes (left) are sold packed in boxes for cooking on an energy-saving stove (right)



(Source: The author, this study)

The informal sector also practises composting at the individual level (households), to produce fertiliser for gardens and fields – a common practice in homes with back-yard gardens. Bio-gas production is also practised in rural areas by some livestock-keepers. Organic waste is also used for animal feed, reducing the need for purchased feed in urban agriculture.

Conclusion

The demand for effective solid waste management is high in Uganda, and indeed in most African municipalities, as waste volumes are increasing, because of rising urban populations. However, waste-collection and disposal levels are still low in all municipalities, resulting in waste piles. This situation, apart from negatively affecting aesthetics, has a direct bearing on social, economic and political development, impacting unfavourably on the municipalities and the urban community.

To address the waste-management challenges, improving funding and developing technical capacity is desirable, while at the same time adapting the population socio-cultural systems to each municipality's mode of development. This means involving all stakeholders at all levels and in all sectors for an integrated approach to the planning and management of solid waste.

There is therefore a need for municipalities to explore opportunities for alternative ways of employing an integrated approach to sustainable waste management, based on the waste hierarchy elements that can be adopted by all stakeholders, formal and informal, to address waste-management challenges. Some of these efforts are of immediate benefit to the community, by creating self-employment and source of income. The involvement of the private sector, NGOs and CBOs can be strengthened through partnerships.

Notes and References

- 1 Van de Klundert, A. & Anschütz, J., 2001. Integrated sustainable waste management – the concept. Gouda: WASTE.
- 2 Okot-Okumu, J. & Nyenje, R., 2011. Municipal solid waste management under decentralisation in Uganda. *Habitat International*, 35, pp.537–43.
- 3 Ibid.
- 4 Achankeng, E., 2003. Globalisation, Urbanisation and Municipal Solid Waste management in Africa. Paper presented at African Studies Association of Australia and the Pacific 2003 Conference Proceedings – Africa on a Global Stage. 1–3 October 2003. Adelaide: The University of Adelaide.
- 5 Ibid.
- 6 Kaseva, M.E. & Mbuligwe, S.E., 2005. Appraisal of solid waste collection following private sector involvement in Dar es Salaam. *Habitat International*, 29, pp.353–66.
- 7 Manga, V.E., Forton, O.T. & Read, A.D., 2008. Waste management in Cameroon: a new policy perspective? *Resources, Conservation and Recycling*, 52, pp.592–600.
- 8 Rotich, H.K., Yongsheng, Z. & Jun, D., 2006. Municipal solid waste management challenges in developing countries: Kenyan case study. *Waste Management*, 26(1), pp.92–100.
- 9 Okot-Okumu, J. & Nyenje, R., 2011.
- 10 Oosterveer, P. & Van Vliet, B., 2010. Environmental systems and local actors: decentralizing environmental management in Uganda. *Environmental Management*, 45, pp.284–95.
- 11 Simelane, T. & Mohee, R., 2012. Future Directions of Municipal Solid Waste management in Africa. Pretoria: Africa Institute of South Africa (AISA).
- 12 Okot-Okumu, J. & Nyenje, R., 2011.
- 13 Achankeng, E., 2003.
- 14 Adebilu, A.A. & Okenkule, A.A., 1989. Issues on environmental sanitation of Lagos mainland Nigeria. *The Environmentalist*, 9(2), pp.91–100.
- 15 Kaseva, M.E. & Mbuligwe, S.E., 2005.
- 16 Scheinberg, A., 2011. *Value Added: Modes of Sustainable Recycling in the Modernisation of Waste Management Systems* (PhD thesis). Wageningen: Wageningen University.
- 17 Okot-Okumu, J. & Nyenje, R., 2011.
- 18 National Environment Management Authority (NEMA), 2007. Clean Development Mechanism (CDM). Uganda solid waste composting project. *State of Environment Report for Uganda 2006/7*. Kampala: NEMA.
- 19 Okot-Okumu, J., 2012. Solid Waste management in African Cities – East Africa. In L.F.M. Rebellin (ed.), *Waste management - An Integrated Vision*. Kampala: INTECH
- 20 NEMA., 2007.
- 21 Okot-Okumu, J., 2012.
- 22 Vanhille, J., Wolf, A., Hansen, K. & Drysdale, D., 2013. Potential pathways for the waste management system of Kasese. Aalborg: University of Copenhagen.
- 23 Okot-Okumu, J., 2012.
- 24 Okot-Okumu, J. & Nyenje, R., 2011.
- 25 Liyala, C.M., 2011. Modernising Solid Waste management at Municipal Level: Institutional arrangements in municipalities of East Africa (PhD thesis). Wageningen: Wageningen University.

- 26 Yhdego, M., 1995. Urban solid waste management in Tanzania issues, concepts and challenges. *Resources, Conservation and Recycling*, 14(1), pp.1–10.
- 27 Palczynski, J.R., 2002. Solid Waste management Options For Africa Report Prepared for Sustainable Development and Poverty Reduction Unit. Côte d'Ivoire: African Development Bank.
- 28 Government of Uganda, 1997. Local Government Act – Act Supplement. *The Uganda Gazette*, 90(10), p.17.
- 29 Katusiimeh, M.W., Burger, K. & Mol, A.P.J., 2013. Informal waste collection and its co-existence with the formal waste sector: The case of Uganda. *Habitat International*, 38, pp.1–9.
- 30 Ojok, O.J., Koech, M.K., Tole, M. & Okot-Okumu, J., 2012. Household willingness to pay for improved municipal solid waste management services in Kampala, Uganda. *Science Journal of Environmental Engineering Research*, 2013, pp.8–16.
- 31 Ako, A.R., 2012. *Solid Waste Management: World Perspective and Cameroon Case Study* (MSc Dissertation). Porto: Fernando Pessoa University.
- 32 Oberlin, A.S., 2011. The Roles of Households in Solid Waste Management in East Africa capital Cities (PhD thesis). Wageningen: Wageningen University.
- 33 Liyala, C.M., 2011.
- 34 Nzeadibe, C., 2009. Solid Waste Reforms and Recycling in Enugu Area, Nigeria. *Habitat International*, 33(1), pp.93–99.
- 35 Vanhille, J., Wolf, A., Hansen, K. & Drysdale, D., 2013.
- 36 Government of Uganda, 1995. National Environment Act Cap 153. *Uganda Gazette*, 88(21).
- 37 Ibid.
- 38 Pictures appearing in Figures 7.2, 7.4 and 7.10 were kindly provided by Ms. Doreen Nakirya, my research assistant during the research for this chapter.
- 39 Okot-Okumu, J., 2012.
- 40 Okot-Okumu, J. & Nyenje, R., 2011.
- 41 Kritika, S., Sohini, P. & Pooja, R.G., 2010. *Decentralisation in Uganda*. India: National Council for Applied Economic Research.
- 42 Francis, P. & James, R., 2003. Balancing Rural Poverty Reduction and Citizen Participation: The contradictions of Uganda's Decentralisation Program. *World Development*, 31(2), pp.325–337.
- 43 Ojok, O.J., Koech, M.K., Tole, M. & Okot-Okumu, J., 2012.
- 44 Awunyo-Vitor, D., Shaibu, I. & Seidu, J., 2013. Urban Households' Willingness to Pay for Improved Solid Waste Disposal Services in Kumasi Metropolis, Ghana. *Urban Studies Research*, 2013, pp.1–8.
- 45 Wasswa, J. & Schluep, M., 2008. *E-Waste assessment in Uganda. A situational analysis of e-waste management and generation with special emphasis on personal computers*. Kampala: Uganda Cleaner Production Centre.
- 46 Ministry of Information and Communications Technology (MICT), 1999. Electronic Waste management Policy for Uganda. Kampala: ICT.
- 47 The number of municipalities in Uganda is increasing unpredictably as new districts are declared by the Executive; hence new municipalities are created to form district headquarters.
- 48 IPCC., 1997. Guidelines for National Greenhouse Gas Inventory. Washington: IPCC.

- 49 Achankeng, E., 2003.
- 50 Kaseva, M.E. & Mbuligwe, S.E., 2005.
- 51 Vanhille, J., Wolf, A., Hansen, K. & Drysdale, D., 2013.
- 52 Okot-Okumu, J. & Nyenje, R., 2011.
- 53 Vanhille, J., Wolf, A., Hansen, K. & Drysdale, D., 2013.
- 54 Katusiimeh, M.W., Burger, K. & Mol, A.P.J., 2013.
- 55 Emission reduction (ER) is the amount of greenhouse gases (in tonne) reduced annually by a nation (defined in Article 6 of Kyoto Protocol).
- 56 Liyala, C.M., 2011.
- 57 Van de Klundert, A. & Anschutz, J., 2001.

CHAPTER 8

The Role of Policy and Institutional Reform in Enhancing the Technical Efficiency of Urban Authorities: Reference to Solid Waste Management in Kampala City, Uganda

Judith Tumusiime Tukahirwa and Najib Bateganya Lukooya

The Challenge of Urbanisation in The Developing World

The wave of urbanisation is a global phenomenon, and there is no doubt that the proportion of the human population living in urban areas is increasing worldwide. Since the industrial revolution approximately three centuries ago, urban systems, and specifically cities, have grown enormously¹ in terms of population size, landscape coverage and socio-economic and political power. Most significantly, surpassing the global population tipping-point from a predominantly rural-subsistence population to an urbanisation cascade has totally shifted the socio-economic equilibrium and state of the global environment.

Currently, more than 50 per cent of the world's population lives in cities, and this proportion is projected to be more than 70 per cent by 2030.² In Europe, North America, Australia and Latin America, the urban population has already surpassed the 70 per cent mark, and the growth rate is at an unprecedented level in Asia, Africa, and the Middle East. Consequently, unlike in the past, urban systems (ranging from small to mega-cities) have become essential niches for human habitation and an economic lifeline support for the global population.³

Africa has the highest rate of urban population growth (approximately 3,9 per cent per year) with over 320 million people, representing 37 per cent of the total population, living in urban areas.⁴ The urbanisation cascade, also associated with the increase in urban population in Africa, is a result of both natural growth and rural-urban migration. However, rural-urban migration, due to deepening rural poverty coupled with inadequate access to social economic services (such as employment opportunities, education, health, water supply and sanitation), has been significant. Therefore, in Africa, the urbanisation cascade is not only a temporal and spatial

demographic shift, but also represents the current social and economic transformation trend in this region.

In sub-Saharan Africa, and specifically East Africa, urbanisation has been characterised by the proliferation and expansion of informal settlements, which are predominantly a hub for the urban poor.⁵ The population in these unplanned settlements forms a significant part of the total population in almost all cities of East Africa. Consequently, this contributes to urban socio-economic disparities, inequitable delivery of social services, gross environmental degradation and public health deficits in existing and emerging towns and cities.

Demographic predictions indicate a 90 per cent human population growth rate in developing countries in the twenty-first century. Therefore planning organised urban systems, especially cities, is not only an option, but also a paramount obligation of governments and urban local authorities. One of the critical elements of urban sustainability is long-term planning, driven by government commitment to socio-economic transformation and development. This is a function of adequate investment in: formulating enabling policies; putting in place relevant laws and regulations; establishment of efficient and dynamic institutions; infrastructure development and delivery of equitable and quality services to the population.

To underpin the resilience of urban development investments on a temporal scale, key players, including political leadership, the private sector, civil society and the general public, must be brought on board. Most importantly, sustaining human livelihood and security by promoting high-quality environmental and public health services is vital, and forms the fulcrum of urban prosperity. Distinct cases of massive transformation of modern, prosperous and 'green' cities around the aforementioned elements has been exhibited by Curitiba in Brazil (Latin-America) and Singapore in Asia,⁶ to mention only two. In East Africa, Kigali, the capital of Rwanda, has demonstrated that with government commitment, developing an organised city is achievable in a reasonably short timescale.

According to UN-HABITAT, key elements of urban prosperity include economic productivity, infrastructure development, improved quality of life, equity, social inclusion and environmental sustainability. Although developing countries are striving to achieve some of these through the millennium development goals (MDGs), the implementation of action is far from a contextual reality. Major complexities include rapid population growth, stochastic socio-economic dynamics and environmental degradation challenges, including climate change.⁷

East African countries, in particular, are constrained economically, but at different levels. However, it is becoming increasingly difficult, across the board, to break even on all fronts of human development and sustainability in terms of quality and equitable delivery of services. Key among the areas affected are health, education,

infrastructure development, agriculture, etc. This means that prioritisation for sustainable urban planning and development is grossly impaired. Very often, central and local governments work with ad-hoc solutions in response to prevailing social, economic, political and environmental challenges.

Generally, governments and urban local authorities in cities in developing countries need to be dynamic and proactive. In line with the aforementioned, long-term planning and strategic thinking is critical, to adequately address current, emerging, and projected challenges. This does not merely require appropriate policy and institutional reforms, but also calls for sound technical competencies and efficiency. Consequently, high-quality service delivery and commitment to achieving a well-defined vision and set holistic development targets can be realised.⁸ For example, although there has been an attempt to invest in improving public health in developing countries, solid waste management (SWM) and inadequate sanitation are still some of the greatest challenges of all time.

Drivers of Urbanisation and Urban Local Authorities in East Africa

As is the case in other parts of Africa, the social and economic conditions in East Africa are extremely dynamic, and very difficult to project.⁹ However, under the prevailing conditions of urban-rural disparity, urbanisation has been inextricably linked to high population growth rates and economic transformation. In many countries of this region, governance and administrative structures are decentralised, although with varying degrees of success.¹⁰ Therefore regional and/or district administrative (decentralisation) units form centres of urban (and city) development. As a result, a country-wide network of urban systems (towns, municipalities and cities) is formed. These are characterised by high population density and intense formal and informal economic activity, coupled with government, development partners and private-sector investments.

Unfortunately, since there is no clear strategy to integrate rural and urban socio-economic systems, the rural-to-urban influx dominates the population migration trend. This leads to the proliferation of many unplanned urban settings (informal settlements) for the predominantly low-income population. Due to lack of long-term planning, the available resources are always thinly spread across many sectors to cater for fundamental livelihood basics of urban dwellers. Therefore, implementation of concrete, long-term projects is grossly constrained. This not only maintains the vicious cycle of urban poverty, poor public health and compromised environmental quality, but also induces negative inertia to social and economic resilience of the local population.

East Africa has, for centuries, been predominantly rural, characterised by subsistence agriculture, including crop-farming and animal husbandry. In addition, traditionally many communities depended directly on natural resources, which provided a multitude of eco-system services, hence significantly contributing to their livelihood.¹¹ However, the high population growth, especially in the last part of the twentieth century, has imposed excessive exploitation pressure on natural resources. This is compounded by massive degradation of land, forests, wetlands and freshwater ecosystems.¹² Unsustainable agricultural practices, including massive encroachment on virgin forest and wetland areas, in order to increase food production, have, over the years, reduced crop yields and the ecosystem-based supply of consumer goods.

Generally, East African governments over the years have planned inadequately and invested insufficiently in sustainable agricultural systems and rural livelihoods to enhance socio-economic resilience to any degree. Also, updated population data and growth projections to inform robust planning are grossly lacking. As a result, both rural and urban systems have gradually but steadily collapsed, culminating in rural poverty and chaotic urban systems. The young generation, particularly, has resorted to the exploration of lucrative livelihood opportunities in major cities and towns, to the disappointment and frustration of many. All the same, the establishment of informal settlements, whose livelihood strategies are primarily centred on daily survival, is already dominating the urbanisation cascade, and is projected to continue doing so.

The concentration of human populations in urban areas, especially cities, implies that they have become hot-spots for economic productivity. Like many other low-income countries, urban authorities in East African cities are heavily dependent on financial transfers from central government to plug any deficits in their operating expenditure. Also, in the past one or two decades, loans and grants from development partners have become critical in addressing infrastructure investments and environmental challenges. Local revenue collection to support city planning and investment programmes is grossly hampered by low-yield taxes and fees from a predominantly poor urban population, and unsustainable public financing models.

Allocation of financial resources to urban development is currently becoming a priority in steering social and economic development for low-income countries.¹³ However, with the numerous competing demands for available financial resources, the gravity of the situation escalates. This, coupled with corruption, institutional failure and bad governance, complicates the urban development sector. It is therefore paramount that optimisation of the meagre resources requires technically sound implementing institutions and efficient accountability mechanisms. This is also critically relevant when implementing projects that are bankrolled by loans from international financing agencies (development partners).

Significant amounts of such funds obtained from development partners have to be paid back from the scarce revenue sources of constrained local economies. In effect, implementing agencies and institutions of government (local urban authorities) have to exhibit the utmost ethical and technical efficiency to optimise social and economic benefits, thereby ensuring the sustainability of the investment. As a key stakeholder, government therefore plays a major role in steering urban transformation and development processes. This could be more effective through the provision of an enabling environment by putting in place appropriate legal and institutional structures.¹⁴

Improving SWM is one of the most effective ways to strengthen overall municipal (urban) management.¹⁵ Also, it is very often a prerequisite for enhancing other essential municipal services, such as drainage, sanitation and public health in general. Therefore, SWM becomes one of the most significant technical performance indicators of sustainable urban development. Currently, the inadequate management of solid waste in a rapidly urbanising East African region is a major impediment to economic productivity and social transformation. This is mainly due to the deterioration in public health and environmental quality, which are inextricably associated with a high disease burden and low per capita productivity – and hence with poverty.¹⁶

Like other developing countries, indiscriminate disposal of solid waste is a common scene in many urban centres of East Africa. This situation is still prevalent, even when relevant legal provisions and urban authorities/institutions exist. Many factors have been put forward to explain this pervading situation. They include, among others: inadequate allocation and mobilisation of financial resources for investment in waste management; high urban population growth, hence increased waste generation; proliferation of unplanned settlements (slum areas); inadequate technical capacity and institutional failure of urban authorities/municipalities; lack of public awareness and participation in waste management; poor and unco-ordinated private-sector involvement; insufficient engagement of civil society organisations (CSOs); lack of local technological innovation and adoption; disparities in SWM services delivery; and poor governance and corruption.¹⁷

The case of Kampala in Uganda, discussed in the following section, illustrates interesting progress toward sustainable waste management. This has been accelerated particularly by government intervention in city administration through timely policy and institutional reform. Driven by its commitment to improve technical efficiency, service delivery and socio-economic transformation, the new city management regime is progressively turning around the waste-management function. The current reforms have not only improved general service delivery and institutional accountability, they have significantly enhanced better SWM, with the potential to change the city's image on multiple levels.

Evolution of Policy and Institutional Structure of Kampala City, Uganda

Kampala City, the current capital of the republic of Uganda, dates back to the sixteenth century (and beyond), when it was a centre of power and administration of the Buganda Kingdom (*Kibuga*) prior to colonial times. However, modern urban development of Kampala started with a municipality, established in the late nineteenth century during early colonial times by Captain Fredrick Lugard. Although both the traditional *Kibuga* and the modern municipality, established by Captain Lugard, coexisted, there were contrasting development trends. The municipal development was more orderly and organised, with well-planned infrastructure and management systems; whereas the *Kibuga* followed haphazard development trends, characteristic of modern slum areas.¹⁸

Urban development institutionalisation, planning and regulation, including but not limited to Kampala City, were established by the British colonial government under the Urban Authorities Act of 1958 (later amended to the Urban Authorities Act, 1964).¹⁹ This act guided the development of well-planned urban systems in Uganda, with organised infrastructure and social service delivery systems such as roads, hospitals, schools, waste-water treatment systems, etc. These were all financed through levied taxes and fees for sustainability. Some of the dilapidated remnants of such systems still exist today, in various urban areas in Uganda. These include Kampala, Jinja, Mbale, Masaka, Mbarara, Gulu, etc. During the same period, solid waste management in Kampala and other urban areas, dominated by Europeans and Asians, was well managed through efficient collection and disposal systems. Kampala Municipality, in particular, was clean at all times.

The dilapidation of infrastructure and the collapse of governance and management systems for Kampala City can be traced back to the period between the mid-1960s and the late 1980s, when political conflict and civil wars became intense. The situation escalated with the total collapse of the economy, compounded by the fact that Kampala was the centre of both political and economic power in Uganda. The change in military regime and political leadership during this period was more of a survival strategy and revenge than a development-driven orientation focusing on economic and social development. Consequently, the turbulent economic and socio-political environment of Uganda did not only halt the development of Kampala City, but also led to gross destruction of the infrastructure and the total collapse of the management systems established during colonial times.

When the National Resistance Movement (NRM) government took over political leadership in 1986, after a guerrilla struggle under the flag of Yoweri Kaguta Museveni, it embarked on rebuilding the country. This also involved the formulation of a new constitution and the re-establishment of government institutions. Under these reforms, a decentralised governance system under the Local Government Act

(1997), Cap 243, was established. Under local government, Kampala City was administered through the Kampala district local government structure, through the Kampala City Council (KCC).

Decentralisation of governance under the NRM government is one of the most ambitious reforms undertaken by Uganda since its independence in 1962.²⁰ The objective of empowering its nationals to participate in the process of development was to improve their livelihood. In 2001, an amendment to the 1997 Act was passed, which culminated in the extensive empowerment of elected local governments, including that of urban councils, of which the KCC was part. An elected Mayor and council member representatives, from the different administrative units in the five divisions of the city, headed the administrative unit of the KCC. The unit also consisted of a technical component, headed by the town clerk and assisted by principal town clerks at the various divisions.

Over the years Kampala City, under the KCC, gradually gave way to a total breakdown of management systems and service-delivery, due to gross mismanagement, fraud and a lack of financial accountability by both technical staff and political leaders. These resulted in massive financial losses, loss of public property, poor service-delivery, infrastructure breakdown and haphazard unregulated development.²¹ The SWM component was particularly affected, and the city was characterised by an accumulation of uncollected garbage, coupled with a widespread waste backlog and a generally filthy environment. Inadequate SWM also resulted in the blockage of drainage systems, leading to uncontrolled floods and the outbreak of disease. The constructed sanitary landfill system was also mismanaged, due to inadequate investment in operation and maintenance, and poor contract management of the landfill's private operator. Consequently, it turned into a dumping-ground.

Following the challenges of Kampala City management, the Government of Uganda decided to pay more attention to Kampala and to elevate its status, not only as the capital city of Uganda, but also to directly administer it. The Government of Uganda decided, by Constitution (Amendment) (No. 2) Act 2005 to confer on Parliament the power to enact an enabling law for the creation of a governing and administrative body for Kampala Capital City. Parliament passed the Kampala Capital City (KCC) Act 2010, to change the status of Kampala from a local government to a central government corporate entity. In the new institution, the Executive Director (ED) is the accounting officer of the authority, who also oversees technical planning and implementation of all city developments. An elected Mayor, on the other hand, heads the political wing of the authority, which is comprised of elected councillors. The key role of the authority's council is to deal with policy aspects of the City, which are implemented by the technical team, headed by the ED. Like all new systems, there

are challenges with understanding the functional dynamics, but, overall, progress is promising, especially with technical service delivery, including the SWM sub-sector.

Implications of Policy and Institutional Reform to SWM in Kampala

Background to the SWM System Reforms

Over a period of two years, the Kampala Capital City Authority (KCCA) focused on putting a new institution in place, which has formed the foundation for the on-going transformation process. Critical to the transformation process was the need to address immediate challenges the city has been grappling with for decades. Identified priority areas that required immediate attention included SWM aspects. In effect, SWM has been highly emphasised and given the utmost attention, mainly to underpin two strategic institutional goals: (i) to improve public health safety and environmental quality in the city; and (ii) to demonstrate institutional efficiency, in order to improve KCCA's corporate image. Consequently a robust, results-oriented and responsive SWM model (Figure 8.1) has been adopted, with the overall goal of transforming Kampala into a clean, habitable and healthy city.

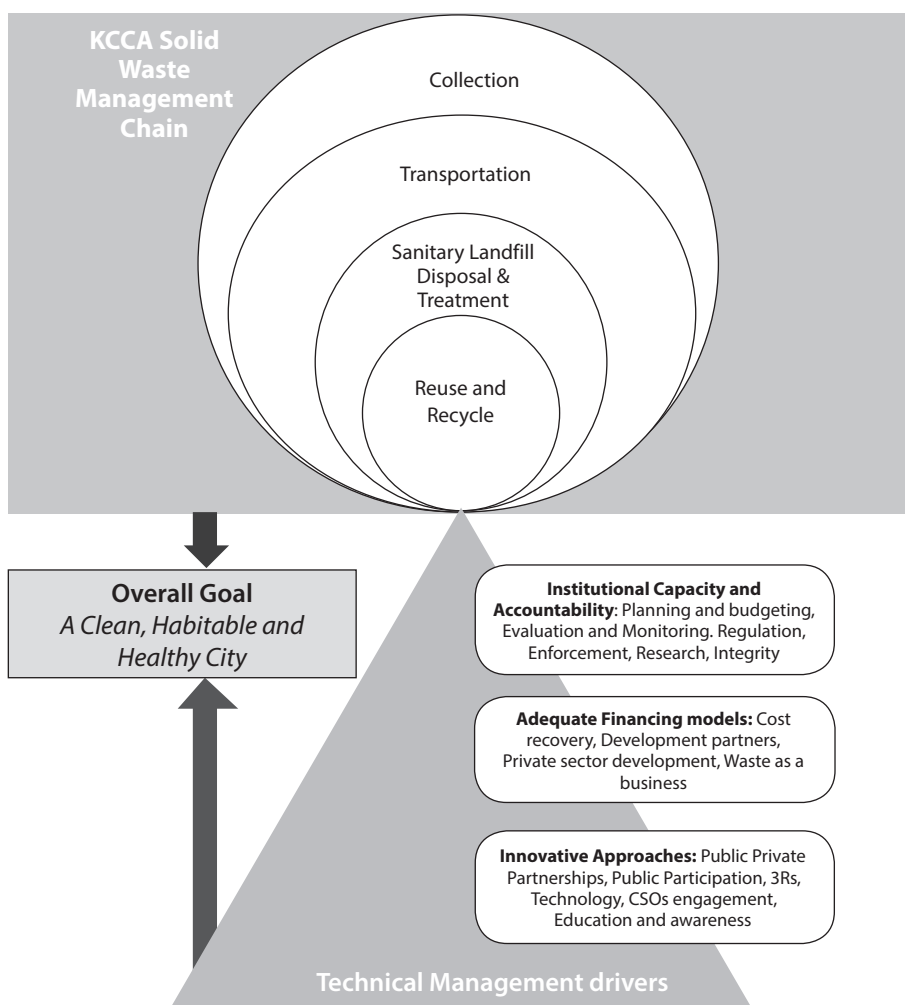
The SWM-Responsive Model

Conceptualisation of the SWM system under KCCA, as described in this section, was achieved through a comprehensive, evidence-based analysis of the following: (i) the solid waste management chain; (ii) interaction with, and engagement of, key stakeholders, including KCCA management and technical staff, civil society, political leaders, development partners and the general public; (iii) review of previous, on-going and planned consultancy/project reports; and (iv) Directorate of Public Health and Environment (DPHE) performance reports. The generated information regarding waste management was used to develop a conceptual framework (or model) for purposes of theoretical illustration and interpretation of the model, presented hereunder.

The KCCA SWM model emphasises an understanding of the local SWM chain, including public practices, to optimise institutional, technical and financial inputs. In addition, robust accountability mechanisms are put in place to ensure value for human and financial resource investment options. As a result, development of dynamic and flexible innovative SWM approaches is enhanced on a temporal scale, as opposed to the traditional 'collection and dumping' routine. KCCA's approach to SWM, therefore, focuses on enhancing efficiency at each stage of the solid waste chain (i.e. collection, transportation, disposal and treatment, and waste re-use/recycling). To achieve this, the city authority emphasises key technical management drivers, which leverage the solid waste management component.

Technical management drivers herein refer to institutional mechanisms, which are adopted to enhance action geared towards achieving a set goal or overall objective. The major technical management drivers, currently adopted to maximise performance potential and including solid waste management, are: (i) development of institutional capacity and efficient accountability mechanisms; (ii) exploration and optimisation of financial resources; and (iii) adoption of dynamic and flexible innovative approaches specifically for SWM.

Figure 8.1: Conceptual model for SWM under KCCA management



(Source: Illustration by Authors)

Institutional Capacity and Accountability

SWM is an intensive service, and requires urban authorities to: develop strong institutional capacity in procurement, contract management and professional labour management; and possess expertise in capital development, budgeting and financial resources management. Therefore, to enhance technical efficiency in public service delivery (including waste management), institutional capacity-building is key. In line with this, KCCA has focused on developing competent, professional, motivated, accountable and ethical teams at all levels of the institution. The SWM component has been particularly prioritised, and forms a core function of DPHE. This commitment also underpins the fact that SWM is a fundamental social contract between the local urban authority and communities within its jurisdiction.²²

Realising that SWM is so dynamic and requires the synergy of multiple approaches, KCCA has developed a multi-disciplinary professional team to spearhead the development of an Integrated Solid Waste Management (ISWM) system. As a result, an array of professionals, including environmental engineers and/or scientists, economists, social scientists, information and communications management specialists, medical specialists, monitoring and evaluation specialists as well as public health scientists, etc., have been brought on board. The mix of different professional backgrounds has enhanced the development of holistic solid waste-management approaches on a city-wide scale. Some of the programmes initiated so far, and clearly on course for success, include: community outreach campaigns and employment creation opportunities in waste management; equitable access to waste management through the provision of collection services to informal settlements; public awareness and sensitisation campaigns; and institutional collaboration (through projects) with other government institutions, the private sector, civil society and development partners, including the International Finance Corporation (IFC) of the World Bank.

In addition, an effective monitoring and evaluation system has been put in place through regular performance appraisals and reports, supported by evidence-based assessments. This is critically essential in terms of human resource performance and financial resources accountability. Furthermore, a corruption-free working environment has been set as a paramount institutional obligation and a corporate identity signature in service delivery. This is promoted through incentives, including: timely payment of salary packages and wages for workers; routine (daily/weekly) sharing of field experiences and peer encouragement; formal recognition by top management for outstanding staff members, including those who resist bribe offers, etc.

SWM Financing

SWM has been constrained for so long by inadequate financing in many developing countries, including Uganda. In terms of equipment and supplies, operation and

maintenance, and timely payment of wages to workers, financial resources are a key driver for efficient management of solid waste. Therefore the commitment of urban authorities to maintaining a clean environment is essential in stimulating sustainable financing innovations.

The major sources of finance for Kampala City have been central government and local revenue. However, due to a narrow revenue base, inefficient revenue-collection mechanisms and inadequate accountability systems, over a period of time, the city has lost significant financial resources. This was exacerbated by institutionalised corruption tendencies, tax evasion, etc. As a result, not only the SWM function has been affected, but provision of other key services and infrastructure development as well. To make matters worse for SWM, there is no direct budget line from central government to support this function. Consequently, it is incumbent upon the urban authorities to think outside the box through creativity, innovation and commitment to mobilise resources to up-scale this critical service.

Table 8.1: Financial allocation to SWM in Kampala City

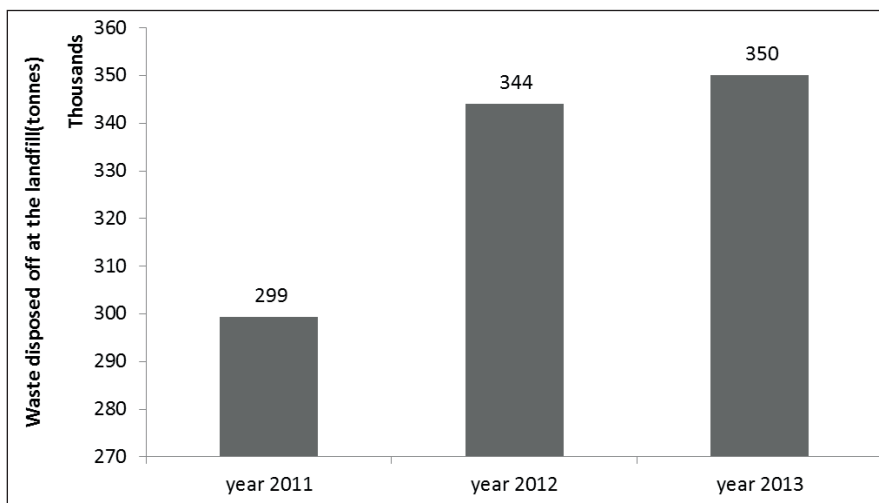
Financial year	2002/03	2003/4	2004/5	2005/6	2006/7	2011/12**	2012/13**
Total budget (US\$ millions)	0.564	1.091	0.728	0.748	0.947	4.313	5.670

** FY under KCCA

(Source: Kampala City Annual Budget)

KCCA's prioritisation of improving public health and environmental quality has resulted in a significant increase in the allocation of money from internally generated funds (local revenue) to SWM in the past two years (Table 8.1), compared to previous KCC regimes. Most importantly, stringent accountability mechanisms to justify value for money have been put in place and emphasised. The significant increase in financial allocation under KCCA has resulted in the following achievements in the SWM of Kampala City:

- (i) Increased solid waste collection and disposal to the sanitary landfill, from an average of 40 per cent (between 2002 and 2010) to 65 per cent (in 2012 and 2013). This is five per cent short of the 70 per cent target initially set for the financial year (FY) 2012/13. This has been due to the purchase of new garbage trucks, more efficient operation and maintenance, and reduced equipment breakdown. Also, there has been increased efficiency in the supervision of routine clean-up activities in the city, especially in public places (streets, markets, etc.).

Figure 8.2: Waste disposal trends at Kiteezi Landfill since KCCA took over in 2011

(Source: KCCA Directorate of Public Health and Environment Performance Report 2012-2013)

- (ii) Increased efficiency of the engineering operations at the sanitary landfill in terms of waste-spreading, soil coverage, compaction and leachate treatment performance, due to improved supervision of contractor operations.

Figure 8.3: Soil covering, spreading and compaction at KCCA Kiteezi Landfill

(Source: Photo taken by Namanya Emily, 2013)

- (iii) Increased compliance of KCCA and private collectors with waste transportation and disposal guidelines, including the use of personal protective equipment (PPE) and specialised trucks with tumpline covers, to reduce waste dispersion.
- (iv) Increased city cleanliness, due to a significant reduction in garbage accumulation and street litter. This is attributed to increased sweeping frequency, vigilant supervision, public sensitisation and enforcement.

- (v) Reduced silting and clogging of drainage systems (Figure 8.2), with the up-scaling of de-silting and garbage collection frequency using casual labourers and community-based organisations (CBOs).

In addition to internal financing, various collaborations with the private sector, CSOs and development partners have been initiated to accelerate the transformation of Kampala City through integrated sanitation projects. These projects include: waste-sorting at source and subsequent re-use; community clean-up campaigns; etc. All these are innovations that directly complement institutional financing and, ultimately, up-scale the solid waste management service within the city.

Figure 8.4: Unclogging drainage systems through improved waste management



(Source: Photos taken by James Semuwemba before –2011 and after –2103 respectively)

Adopting Innovative Approaches

Streamlining Private Sector Operations

The uncoordinated operation of private garbage collectors in Kampala City has been a major stumbling block to SWM, especially due to the illegal disposal of waste in drainage systems, wetlands, and undeveloped areas. Consequently, the DPHE team initiated a massive, city-wide campaign to organise private companies through registration, workshops and sensitisation meetings.

This was aimed at: (i) developing their operational capacity and enhancing compliance with existing laws and regulations regarding SWM; (ii) organising them into a collaborative framework (association) for effective coordination and mobilisation; (iii) professionalising the private SWM business through legalised registration/licensing; (iv) re-defining their scope and capacity of operation for efficient monitoring; and (v) networking between local and international partners to enhance capacity synergies. In addition, informal solid waste collectors are organised into CBOs to

formalise their operations and create more income-generating opportunities, especially for the youth and women's groups.

In line with streamlining private SWM operations, the city has been demarcated into operational zones based on population density, which correlates with waste generation. This innovative approach is geared towards effective private-sector coordination, ease of monitoring, and regulation of operations by KCCA. It is also aimed at increasing accountability, social and spatial proximity, and equitable service-delivery to the city's population. In this zoning model, contracted companies or firms will be expected to deliver quality SWM services, on behalf of KCCA, as per the set guidelines, relevant laws and regulations and contract obligations. It is also envisaged that the hardware operations of KCCA will be reduced to focus on effective planning, monitoring, and evaluation of performance, in addition to enhancing public participation. This is, furthermore, a strategic intervention to up-scale job creation through the private sector on a city-wide scale.

Public-Private Partnerships (PPPs)

Currently, formal private-sector participation in the urban SWM chain is a key engine for up-scaling this service in cities worldwide. Also, urban communities are increasingly organising themselves into small, informal, community-based organisations (CBOs) to engage in waste management for households and business communities, especially in Kampala. These are initiatives that ultimately offer opportunities for improving the livelihood of the urban poor, as well as maintaining a clean and healthy living environment within the city. In developing cities, such as Kampala, besides improving service-delivery through various business-oriented models that suit the market, the private sector accelerates development processes. This can be enhanced through direct investment into the financially-crippled sanitation and solid waste management sector, coupled with the creation of employment opportunities. In line with the aforementioned, KCCA has engaged the IFC to develop a well-structured PPP, based on international performance best practices. Although this project is still in the initial stages of development, it is an indicator of the high level of commitment and technical vision required to transform the SWM sector.

KCCA also realised the constraints of public financing, which in many aspects affects sanitation and SWM services rendered to the city's population. Consequently, a number of initiatives to organise and develop a robust private sector have been rolled out, as discussed earlier. Some of the most significant ones include the registration of the private solid waste collectors and transporters into an association, which can offer a number of benefits. These include: (i) enhancing collaboration in public awareness and sensitisation campaigns; (ii) mobilisation for the clearance of waste backlogs through community service initiatives; and (iii) a platform for

capacity-building of the private sector in international service-delivery best practices. In addition to the association, informal and casual workers have been organised into community-based organisations, which makes it easier for KCCA to engage them in many aspects of waste management and other community development projects.

Public Participation

The process of city transformation and development requires public buy-in for sustainability. KCCA has embarked on rebuilding its corporate image to develop public confidence and participation in different city development projects, including city clean-up campaigns. Besides massive sensitisation campaigns, monthly clean-up programmes have been initiated and implemented by KCCA, together with the general public, in communities, markets, hospitals, major roads, etc. This kind of programme has also been found to be effective in Kigali, the capital city of Rwanda. Although the approaches may be different, the ultimate goal is the same. In such exercises, public participation is emphasised, to embrace the strategic goal of transforming the city into a clean, habitable, and healthy one.

Figure 8.5: Clearing solid waste backlogs by engaging communities through participation and sensitisation



(Source: Photos taken by Josephine Kitaka, 2013)

Another interesting public participation innovation, which also aims at promoting equitable solid waste management services, especially to the urban poor, is the self-loading programme. Many of the urban poor communities, who in most cases cannot afford the services of private waste collectors, reside in informal settlements (slum areas). In addition, due to poorly-developed road infrastructure in these areas, the KCCA garbage trucks cannot access them for waste collection purposes. The accumulation of waste in these settlements can create an appalling scene, not only in the informal settlements, but also along roads and in drainage channels in close proximity. All these ultimately cause huge public health effects and environmental degradation constraints. Consequently, KCCA came up with a routine self-loading programme, in which households in communities are mobilised to bring their waste to garbage trucks that park along accessible roads. Mobilisation and sensitisation of communities in terms of this programme is essential. Therefore, various means to pass the message to household level is a key priority. In Kampala, the local leaders play a major role to supplement the public messages which are disseminated through garbage-truck megaphones, radios, community meetings (Barazas), etc.

Figure 8.6: Community self-loading of waste in informal settlements



(Source: Photo taken by James Semuwemba, 2013)

To enhance innovative waste-management practices in communities, re-use and recycling of waste have been popularised and promoted. This is mainly at informal level and on different scales, city-wide. The materials scavenged along the waste-stream mainly consist of plastic, plastic bags, metal and glass, etc. To KCCA, removal of these materials from the waste-stream is essential in increasing the life-span of the landfill. In addition, the practice of sorting gives leverage to environmental sustainability, by reducing the accumulation of non-biodegradable materials. To the

households and communities involved, the re-use offers income-generation opportunities. Realising this potential, KCCA is developing waste re-use market networks between community-based informal waste-collectors and established re-usable product processing and recycling centres/industries. These market linkages are also enhanced by putting in place demonstration centres, facilitated by partner non-government organisations (NGOs). The making of briquettes and compost units, in particular for cooking and manure production, is becoming very popular.

Although at micro-level, public participation involves political dynamics with stochastic politicisation side effects (e.g. de-campaigning development projects) among the general public. Evidence of major success factors has been realised, as highlighted above. Increased public involvement, support from central government, involvement of schools and school children as change agents, corporate social responsibility projects from the private sector and CSO partnerships with KCCA are particularly good indicators of accelerated progress in the sanitation and waste management of Kampala City. The involvement of schools, in particular, has brought about a multiplier effect, since it spills over to households and communities. It is therefore envisaged that these synergies will gradually lead to behavioural changes in the city's population regarding sustainable waste management, eventually leading to a cleaner city.

Conclusion

The transformation process in Kampala City demonstrates a model of enhancing technical efficiency through institutional and policy reforms. Although these reforms come with socio-political challenges, including resistance as the worst-case scenario, the socio-economic benefits are critical in underpinning the success of such fundamental decisions. Most importantly, high-level political commitment and support, as well as spearheading social and economic development from central government, are critical starting points. This is particularly paramount to institutional performance, especially in urban development. Since urbanisation is a global phenomenon of the twenty-first century, governments must develop robust and dynamic institutions and make appropriate investment choices. This can enhance sustainable development of urban landscapes, around which human livelihood and prosperity will be ensured for the next generations.

SWM is one of the critical challenges of developing cities, due to stochastic demographic changes, coupled with unplanned and unregulated developments. Therefore, sustainable and prosperous cities can be linked to effective SWM systems. These can eventually enhance adequate public health safety and sustainable environmental quality. It is not enough to have relevant policies, laws and regulations regarding

waste management in place; the building of efficient and pro-active institutions is essential. By doing so, effective planning, innovative technical efficiency and high-quality service delivery, including SWM, are ensured.

The transformation of KCC to the KCCA in Uganda, following the enactment of the KCCA Act of 2010, provides a novel tipping-point underlying institutional reforms in developing cities. More so, a gradual shift from a filthy city to a cleaner and greener environment in Kampala within two years of the KCCA takeover is a fundamental transformation signature of technical efficiency in the SWM sub-sector.

The SWM model adopted by KCCA has brought quick-win achievements, accelerated by institutional capacity and accountability. These are coupled with the development of innovative financing models and the use of sound technical approaches at different administrative levels. Although all these developments are constrained by various social and political challenges, the potential for transforming Kampala into a sustainable city is very promising. However, this transformation can only be sustained if current central government support and commitment is maintained. In addition, bringing on board a mix of stakeholders, including from the private sector, civil society, and development partners, along with enhancing public participation, are critically essential.

It is demonstrated in this case-study that the role of governance in providing sustainable solutions to urbanisation challenges is key. By rethinking policy and institutional structures, multiple benefits are achieved. These may include high-quality delivery of services and infrastructure development, which enhance human security, environment and health sustainability. In addition, these multiple, positive urban development drivers induce a conducive environment for economic productivity, with a wide range of opportunities for public, civil society and private-sector participation.

Notes and References

- 1 UN-Habitat., 2013. State of World's Cities, 2012/2013: Prosperity of Cities. New York: Routledge.
- 2 Cunningham, P.W. & Cunningham, A.M., 2010. Environmental Science: A global concern. New York: McGraw-Hill.
- 3 UNFPA., 2012. Population Dynamics and Sustainable Development. Issues brief for RIO+20, United Nations Conference on Sustainable Development. 20–22 June 20102. Rio de Janeiro.
- 4 Jacobsen, M., Webster, M. & Kalanithy, V., 2012. The future of Water in African Cities: Why waste water? Washington: Word Bank.
- 5 Pieterse, E., 2010. Filling the Void: Towards an agenda for action on African urbanisation. In E. Pieterse (Ed.), *Urbanisation Imperatives for Africa: Transcending policy inertia*. Cape Town: African Centre for Cities.

- 6 Tan, Y.S., Lee, T.J. & Karen, T., 2009. Clean, Green and Blue: Singapore's Journey towards environmental and water sustainability. Singapore: Institute of Southeast Asian Studies.
- 7 UN-Habitat., 2013. Water and Sanitation in the World's Cities: Local Action for global goals. New York: Routledge.
- 8 Muhairwe, T.W., 2009. Making Public Enterprises Work: From despair to promise. A turnaround account. London: IWA.
- 9 AfDB., 2011. *Africa in 50 years' time: The road towards inclusive growth*. Tunis: Africa Development Bank (AfDB).
- 10 Olowu, D., 2003. Local Institutional and Political Structures and Processes: Recent experience in Africa. *Public Administration and Development*, 23, pp.41–52.
- 11 Denny, P., 2001. Research, capacity building and empowerment for sustainable management of African wetland ecosystems. *Hydrobiologia*, 458(1), pp.21–31.
- 12 MEA., 2005. *Ecosystems and human well-being: Wetlands and Water Synthesis*. Washington: World Resources Institute.
- 13 Van Dijk, M.P., 2008. Urban management and institutional change: An integrated approach to achieving ecological cities. Rotterdam: Institute for Housing and Urban Development Studies.
- 14 Tukahirwa, J.T., Mol, A.P.J. & Oosterveer, P., 2012. Comparing urban sanitation and solid waste management in East African metropolises: The role of civil society organisations. *Cities*, 30, pp.204–11.
- 15 Achankeng, E., 2003. Globalisation, Urbanisation and Municipal Solid Waste Management in Africa. Paper presented at African Studies Association of Australasia and the Pacific 2003 Conference Proceedings – African on a Global Stage. 1–3 October 2013. Adelaide: The University of Adelaide.
- 16 Hoornweg, D. & Bhada-Tata, T., 2012. What a Waste: A Global Review of Solid Waste Management (Urban Development Series Knowledge Papers no. 15). Washington: World Bank.
- 17 Palczynski, R.J. & Scotia, W.N., 2002. Study on Solid Waste Management Options for Africa. Abidjan: AfDB.
- 18 Nawangwe, B., 2009. The evolution of the Kibuga into Kampala's City Centre – Analysis of the transformation of an African city. Kampala: African Perspectives.
- 19 Nilsson, D., 2006. A heritage of sustainability? Reviewing the origin of large scale water and sanitation system in Kampala, Uganda. *Environment and Urbanisation*, 18(2), pp.369–85.
- 20 Kritika, S., Sohini, P. & Pooja, R.G., 2010. Decentralisation in Uganda. Kampala: National Council of Applied Economic Research.
- 21 KCCA, 2013. Performance Highlights at 2 years. Kampala: Kampala Capital City Authority.
- 22 Tukahirwa, J.T., Mol, A.P.J. & Oosterveer, P., 2011. Access of urban poor to NGO/CBO-supplied sanitation and solid waste services in Uganda: The role of social proximity. *Habitat International*, 35, pp.582–91.

CHAPTER 9

Technology Must Seek Tradition: Re-engineering Urban Governance for Sustainable Municipal Solid Waste Management

Martin Oteng-Ababio

Introduction

In the last two decades, most urban centres in Ghana have witnessed increased growth, without a corresponding increase in infrastructure services, with the resultant sprawl leading to increased urban poverty, widespread slums and unbundling of public services.¹ Another challenge relates to municipal solid waste management (MSWM) and, by extension, urban environmental sustainability.² Under the Local Government Act 462, this responsibility falls within the ambit of metropolitan, municipal and district assemblies (MMDAs), yet it remains among the most poorly rendered services. Current systems being applied are unscientific, outdated, inappropriate and inefficient; while population coverage is low and the poor are marginalised.³

The most disadvantaged are residents in low-income and slum communities, who constitute about 70 per cent of the urban population.⁴ Based on the 2010 population estimate of 24.6 million,⁵ and with an average daily waste-generation per capita of 0.45 kg,⁶ Ghana generates about three million tons of solid waste annually.⁷ Studies, however, show that only about 10 per cent of the generated waste is properly disposed of,⁸ while the rest is neither properly contained nor recycled. Apart from the environmental stress this situation gives rise to, it also tends to create an economic niche for informal waste-pickers, who have capitalised, for years, on non-available and inadequate municipal services to such communities in order to fill the vacuum.

In metropolitan Accra, only 20 to 30 per cent of the four million residents benefit from home collection,⁹ while the remaining 70 to 80 per cent dispose of their waste at community dumps, in open spaces, in handy bodies of water, and in storm-drain channels.¹⁰ The public health implications of such practices remain daunting. A Ghana Health Service report indicates that six of the top 10 diseases are related to poor environmental sanitation, with malaria, diarrhoea and typhoid fever jointly accounting for 70 to 85 per cent of out-patient cases at health facilities, or 4.9 per cent of the country's Gross domestic product (GDP).¹¹

Faced with such challenges, the authorities tend to adopt 'solutions' that are rather complicated, and usually without merit in terms of reality. Their centralised and un-diversified approaches do not distinguish between the heterogeneity and neighbourhood specificity in the city. They tend to pursue bureaucratic and top-down approaches that are quite capital-intensive, and which require the use of advanced technology.¹² The bane of such conventional solutions relates to seeing waste as a disposal problem, rather than as a resource-management one. The focus then tends to be on maximising refuse collection and upgrading disposal facilities, instead of giving the highest priority to waste reduction, re-use and recycling.¹³

Meanwhile, prior studies have revealed that the abundance of unskilled and cheap labour and the scarcity of capital in most cities makes it economic sense to opt for a MSWM solution that creates income opportunities for the urban poor.¹⁴ Additionally, the physical morphology of most low-income areas is characterised by narrow, hilly and unpaved roads, which are often not friendly to conventional refuse-collection trucks. This gives a comparative advantage to the informal collectors, who use tricycles, trucks, push-carts and the like to ply their trade. In addition, the lack of formal job opportunities encourages the majority of migrants, women and children to engage in scavenging as a livelihood strategy.

In the circumstances, the author argues that for effective MSWM, low-income areas need an approach that operates better than conventional solutions: they need affordable solutions that work well in a local context, create jobs, protect the environment, promote community participation, encourage and support the entrepreneurial spirit in the community, and that recognise the contribution of informal waste-collectors and scavengers. This will promote investment in locally-made collection vehicles and equipment, which tend to be appropriate to the conditions in which they operate.

This chapter seeks to examine the MSWM systems in low-income communities in Accra, illustrating why some policy options fail, and the way forward. Specifically, the study makes a compelling case for the re-conceptualisation of Public private partnership (PPP) in MSWM, taking into consideration the concerns, interests and challenges of all parties involved in such a partnership – public, private and service beneficiaries. As a way forward, the author proposes the adoption of a model that integrates the formal and informal sectors for sustainable MSWM. The data presented in this chapter draw on a number of research works published between 2006 and 2012.¹⁵ It has also benefited immensely from earlier studies, both in and outside Ghana, that engage with MSWM in low-income countries.¹⁶

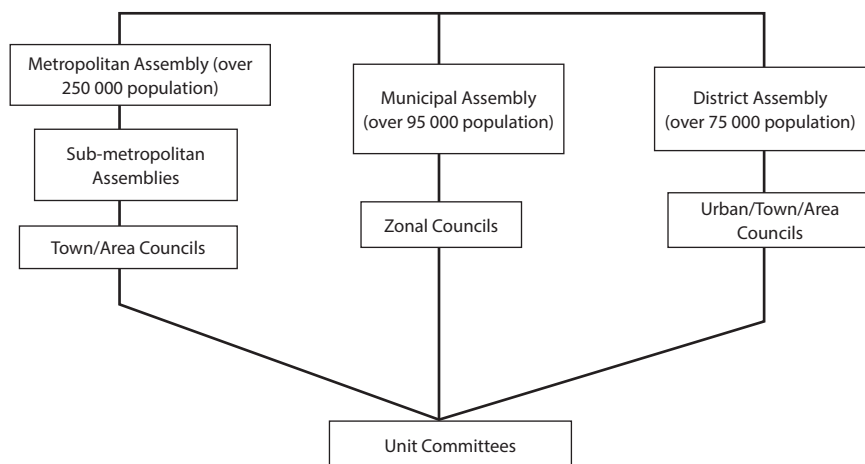
Institutional Arrangements for Solid Waste Management

Prior research findings confirm studies done by Songsore et al.,¹⁷ and Fobil et al.,¹⁸ which showed that solid waste collection is generally serviced under the house-to-house (HtH) and/or community container collection (CCC) systems. The HtH system is generally predominant in middle-income and upper-income, low-density zones of the city, where infrastructure facilities are favourable, while CCC is implemented in low-income, high-density communities. It is also established that in the low-income, high-density areas, waste is often dumped in gutters, drains and streams, as a result of CCCs being left unattended-to for as long as two or three weeks at a time, often as a result of companies not being paid regularly by the local government for pick-up services.¹⁹

This condition is also related to the distances residents often have to travel to access the communal container sites. Earlier studies²⁰ have established that there are maximum travel thresholds within which residents will voluntarily access the CCC, and that once this is exceeded, utilisation tends to fall off considerably. Indeed, the studies have established that the long distances residents have to travel to access a container (in some cases more than 200 metres), only to find it overflowing in most cases, serves as sufficient deterrent for them to look for alternative dumping sites, which invariably are very close to their living places.

The Role of the State

The state's role in MSWM dates back as far as 1898, when the colonial government established the Accra City Council (ACC) and charged it with the responsibility of keeping the city clean.²¹ In 1988, the government embarked on decentralised administrative and development planning to encourage greater local autonomy and to promote more efficient and rapid development. Under the policy framework, MMDAs became the highest political, administrative and development agents in their areas of jurisdiction. The country is currently divided into 10 administrative regions, and each region in turn is divided into districts (270 districts, as at 2012). The districts are further sub-divided into sub-metropolitan councils, zonal councils, urban/town/area councils and unit committees, as illustrated in Figure 9.1. This spatial structure forms the local government system, which is made up of a four-tier metropolitan and three-tier municipal or district assemblies structure.

Figure 9.1: Local government system: district and Sub-district structures

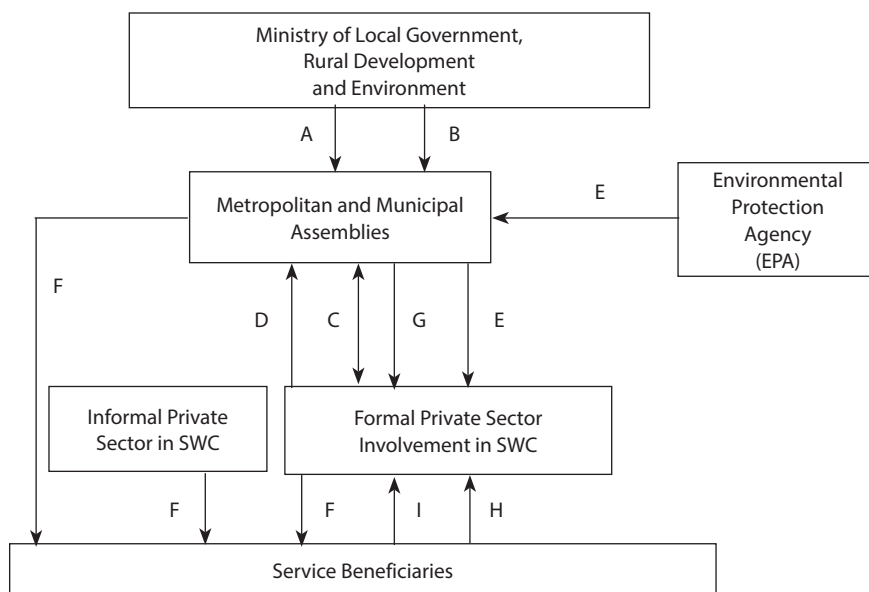
(Source: Oteng-Ababio, M., 2007)

The Local Government Act (Act 462 of 1998) charges the various decentralised MMDAs, through the Ministry of Local Government and Rural Development (MLGRD), with responsibility for SWM. However, regulatory authority is vested in the Environmental Protection Agency (EPA), under the Ministry of Environment and Science Technology and Innovation (MESTI). The EPA has the responsibility for setting environmental quality standards and ensuring their enforcement. The assemblies are further to enact by-laws regulating solid Waste management (SWM) and to strengthen their local unit committees, in order to protect and manage their respective environments. The Waste Management Department (WMD) was established in 1985 by the assemblies to manage environmental sanitation services through the collection, storage, transportation and disposal tasks. The department is also responsible for monitoring the performance of private waste collection firms. Table 9.1 sets out the role of some key stakeholders in MSWM in Ghana.

Table 9.1: Responsibility of key stakeholders in MSWM in Ghana

Service beneficiaries	The main interest of households, especially residential households, is to receive effective MSW services. Waste-disposal is usually not their priority, in as much as it is not affecting their surroundings. In low-income areas, however, as a result of a lack of other services, such as electricity, water and other sanitary services, solid waste is normally not given much attention, and is usually dumped indiscriminately. Improvement of waste-collection services may be a priority only when the other services are made available, and people become aware of the negative impact of poor SWM. Community based organisations (CBOs) are, however, informal organisations formed by members of the community to address the community's needs. They may also be formed as a result of poor environmental conditions or service-provision, and respond to this by initiating SWM operations, such as primary collection and street-cleaning. They petition the government to improve services or environmental conditions within the community, and have the potential to manage local solid waste, if properly organised. Provision of social services is their primary motivation, rather than profit-making.
Non-governmental organisations	Can act as intermediaries between the government and the private sector. Their scope of work may include creating awareness of SWM problems, formation of CBOs and contributing to organisational capacity. They often serve as communication channels between communities and the government sector, representing the community in municipal planning. Implementation of processes, dissemination of information and social concerns for waste-pickers may also be a motivating factor, and the driving force of their activities is mainly to achieve a goal, rather than profit-making.

Similarly, a Metro Environmental Health Department (MEHD) has been established in place of the previous Medical Officer of Health Department (MOHD), known since colonial times as the '*tankas*' (a corrupted form of 'town council' officials) or '*samansaman*' (meaning the one who summons). Its traditional role has always been that of 'sanitary inspector', a quasi-police force whose job was to enforce by-laws and statutory health regulations on households, food vendors, abattoirs, etc., and check that the necessary health certificates were in order.²² Figure 9.2 presents the relationships between the key stakeholders.

Figure 9.2: Relationships between stakeholders in MSWM

(Source: Oduro-Kwarteng, S., 2009)

- A - Sanitation and solid waste policies formulated for the Assembly to implement
- B - Provision of funds for SWC activities
- C - Submission of reports by private companies and access to data from Assembly
- D - Payment of charges to the Assembly by private companies
- E - Supervision and monitoring of activities of service-providers
- F - Rendering of services to beneficiaries by the Assembly or private companies
- G - Release of funds to private companies for services rendered
- H - Payment of user charges to private companies by service beneficiaries
- I - Complaints about service quality by beneficiaries.

Read in conjunction with Figure 9.2, and as already highlighted, the MLGRD formulates solid waste and sanitation policies; provides an oversight role (A) to the Assemblies; and also gives subsidies (B) for provision of solid waste collection (SWC) services. The EPA monitors and supervises the activities of the Assemblies; especially disposal of solid waste. The relationships between the Assemblies and the private sector involve the submission of reports by private companies; payment of charges; and monitoring and supervision of the activities of private service-providers by the Assemblies. The Assemblies and private companies render services (F) to service beneficiaries. The private companies recover the cost of services rendered through

subsidy payments by the Assemblies (G) and payment of user charges (H) by service beneficiaries.

The interface between the stakeholders suggests that achieving the Millennium Development Goal (MDG) 7 (ensuring environmental sustainability), for example, will require efforts in all aspects of the environment, with MSWM being crucial in this regard. It calls for urban waste studies, which take into consideration not only the formal structures of government, but also the informal ones created by civil society – CBOs, etc., – and their relationship with formal structures for collection, transportation, and disposal of waste.²³

The potential for establishing effective institutional arrangements for MSWM depends largely on the existing systems of urban governance, which refers to the successful management of community affairs through the mixing of private, public, and voluntary actors. Ironically, the state policy acknowledges the interaction with the private sector, yet, at implementation level, the implementing authority (Assemblies) seems not to recognise the non-registered private sectors (*kaya bola*), which are the lifeline of the MSWM system.

The Role of the Private Sector

The involvement of the private sector in public service-delivery was introduced at the beginning of the 1990s to recover the systemic downturn in the performance of the country's public institutions. There was strong consensus among development experts that the private option was a 'magic' solution to inefficiencies in public institutions.²⁴ It was argued that partnerships would reduce and stabilise the cost of providing services by using the most productive and cost-effective options, among others. It was also anticipated that there would be efficient operation and compliance with environmental regulations.²⁵ Such partnerships are described as the transfer and control of the responsibility of service-provision, either wholly or partly, from public-sector entities to privately-owned establishments.²⁶ Schubeler is of the opinion that, due to their profit orientation, private enterprises can, under appropriate conditions, provide MSWM services more effectively and at lower cost than the public sector.²⁷

Accra's experience with privatised MSWM dates back to 1994, when the city awarded a five-year franchise for collecting wastes to a private company. Studies show that, in most cases, PPP is usually an exercise of meshing political capital with governmental responsibility.²⁸ Many staff positions, jobs and contracts are politically linked, and thus the management of public services can be disrupted cyclically with every election.²⁹ It is also important to state that most approaches to the privatisation of MSWM are based on the 'user fee' system, or on the ability to pay. In that case, the poor residents in slums and informal settlements are automatically neglected,

because they are unlikely to be attractive to business. It is equally true from the local government point of view as, faced with limited budgets, the metropolitan authorities normally tend to handle the rich less badly than the poor.³⁰

Thus, private sector involvement does not, in itself, guarantee effective and low-cost service delivery, especially in serving the urban poor.³¹ Not only are the poor least able to support waste collection through their own tax base or through user fees; they also generate the least-valuable garbage, and the highest collection cost for private service-providers. The low-cost solution therefore calls for more creative service provision and extensive mobilisation of community members to clean up their own neighbourhoods.³² In the slums of Curitiba-Brazil, for example, with similar challenges, the municipal authority motivates people to dispose of their garbage by exchanging their bags of garbage for food.³³ Such creative *modus operandi* is paramount in low-income communities, to ensure that the community receives its fair share of effective urban environmental sanitation.

The Role of the Informal Sector

The fact that, in most developing and transitioning countries, infrastructure and an organisational system for SWM is insufficient, has been covered by acres of print.³⁴ Municipalities and formal service-providers can neither provide a waste-collection service to all, nor guarantee effective recycling and environmentally sound treatment or disposal. Only the affluent seem to have enjoyed secured and guaranteed services. This is where the services of informal waste-pickers contribute significantly to MSWM and resource efficiency – by collecting, sorting, trading and sometimes even processing waste materials.

In most Ghanaian urban spaces, the organically-grown informal sector activities have demonstrated themselves to be highly adaptable, flexible, and able to respond quickly to demand-driven forces. Participants in the sector constantly come up with adaptive strategies to access waste and circumvent barriers, while at the same time integrating new systems as they emerge. These activities not only provide an income opportunity for as much as one per cent of the urban population, but also serve the protection of natural resources and the environment by recovering up to 20 per cent of municipal wastes in a self-financing system. Within some communities, their work is responsible for between 50 and 100 per cent of all waste activities.

This means that they make an important economic contribution to reducing the burden of SWM for which a city is responsible. Experience shows that informal workers often achieve higher recycling rates (which also reduces greenhouse gas emissions) than formal recycling systems.³⁵ Yet most of these workers experience poor working conditions; their contribution is not acknowledged; and they are often harassed and, in some cases, persecuted by the public and the authorities.

The Case of Asmare in Belo Horizonte – Brazil

Belo Horizonte has a population of 5,5 million, accounting for 28 per cent of Brazil's population, and it is the second-largest state.³⁶ It produces around 1 296 566 tonnes per annum of solid waste,³⁷ or about 1,5 kilograms per person per day. Since the 1960s, many poor residents, popularly called *catadores*, worked at the city's open dump, earning a living by reclaiming saleable materials. Currently, the number of informal workers (*catadores*) engaged in recycling stands at 2 685.³⁸

In 1973, the local authority closed the dump-site when a sanitary landfill was created without recourse to the plight of the *catadores*, who then took to the streets. They were excluded and persecuted; the population viewed them as beggars or criminals. At that time, Belo Horizonte had no formal source-separation scheme. Any recycling was done by the *catadores*, who rummaged through the waste put out on sidewalks or streets for collection by city trucks.

In 1990, the first association of *catadores* – ASMARE – was set up through the efforts of a local NGO called *Pastoral de Rua*, which promoted the right to earn a living from recyclables. At the time, most *catadores* slept on the streets to guard their recyclables, as there were no storage areas. In 1993, the Public Cleansing Agency (SLU), which has a mandate to deliver MSWM services, implemented an integrated system, which included the following:

- upgrading operations at the existing landfill;
- selective waste collection;
- a recycling programme for civil construction waste;
- composting of organics;
- environmental education;
- improving working conditions of formal workers (sweepers and collectors); and
- integration of informal workers into formal SWM processes.

In the same year, SLU undertook a consultation process with ASMARE, and a mixed system, with a drop-off scheme and the formal recognition and support of *catadores*, was introduced. The waste-pickers' working conditions improved greatly, which helped to attract new members to ASMARE: from an initial membership of 31 pickers in 1993, the association at the time of writing has grown to 380 members. In terms of production, collection increased from 15 tons per month in 1993, to 450 tons per month in 2010. The impact in terms of income-generation can also be cited: according to Didero,³⁹ 54 per cent of the associates earn up to two minimum salaries, 40 per cent earn between two and four salaries, and six per cent earn five minimum salaries.

The Case of Cataderio in Maputo, Mozambique

The Municipality of Maputo (with a 2010 population of one million) and *Gesellschaft für Technische Zusammenarbeit* (GTZ) jointly embarked on a project to improve waste collection, recovery and disposal, under a 'Waste Management in the Greater Area of Maputo (AGRESU)' framework. Prior to the launch of the project, many outlying low-income areas had no collection service, and *catadores* used to work at the municipal landfill under extremely bad conditions, collecting recyclable materials from recently-delivered household garbage. With the support of the programme, the *catadores* were registered as co-operatives, in order to carry out joint activities more efficiently and at a higher standard, and were integrated into the formal collection service for hitherto-deprived areas.

Additionally, a centre was built for separation and pre-treatment of recyclable wastes. The integration has had considerable success: 45 per cent of the poor areas of the city are now covered by the collection service provided by small enterprises operated by previously informal waste-collectors. This means that 450 000 citizens now have a waste-collection service, while the new small enterprises provide employment for 250 people. The recycling centre sells high-quality recycled plastics to the local recycling industry, and no longer needs external financial support. The employees have a significantly higher income than before.

The Case of Zabbaleen – Cairo, Egypt

One city where the authorities defied the informal sector with dire consequences is Cairo. The city, with a population of 14.5 million in 2011 (and a density of 1 658 people per square kilometre) generates approximately three million tons of MSW annually. Waste-collection and transportation efficiency ranges between 15 and 65 per cent, even after MSWM had been privatised. The city authorities' privatisation decision-making processes were influenced by the tenets of globalisation, market forces, political expediencies and other external considerations, without giving much weight or attention to possible local content. The Zabbaleen were a group of waste workers; mostly Coptic migrants who had achieved a highly effective and sustainable waste-collection system.⁴⁰ The Zabbaleen secured their living by feeding their pigs the collected organic waste, and selling the animals for a profit. In addition, they sorted the garbage into marketable recycling materials such as paper, glass, and scrap metal. According to Iskandar,⁴¹ the members were very adept at what they did, diverting 70 to 80 per cent of waste from landfills through recycling, compared to a 30 per cent 'best practice' figure from global corporations. Additionally, inhabitants paid only minimal fees for their garbage collection service. According to Wilson et al., in 2006,⁴² though the Zabbaleen lived and worked in disastrous conditions in settlements on the fringes of the city and were highly marginalised and stigmatised, they were nevertheless grateful for the income opportunity.

However, in the 1990s, and without reference to the Zabbaleen, who were used to the hard, dirty, smelly, and highly stigmatised nature of waste work, Cairo implemented a privatisation process, by commissioning several European multi-national waste companies to deal with waste removal in the city. Commenting on the outcome of the privatisation process, Wilson et al.⁴³ stated emphatically that ‘the new system is a complete failure’, explaining that though the companies were only required to achieve a recycling quota of 20 per cent, they achieved even less. The gaps and weaknesses identified as affecting service provision in Cairo include:

- lack of alternative mechanisms for collection of service charges;
- the important role of local companies, NGOs and the informal sector (the Zabbaleen) has not been recognised by the municipal and national governments;
- the fact that there is a need for implementation of a long-term and focused sanitation awareness campaign and education in waste management; and
- that engineered landfills do not exist at this time.

Undoubtedly, most African countries could profit from the experience of the Zabbaleen, by importing their know-how and competitively-priced waste processing equipment.

The Kaya Bola Experience in Accra, Ghana

Ghana has a long history of informal waste-pickers, commonly referred to as *Kaya Bola*,⁴⁴ participating in waste-collection and recycling, working daily on the streets and in the landfills in search of recyclables.⁴⁵ Their involvement is as a result of irregular, skewed and inefficient services from the public sector.⁴⁶ Such unsustainable services often result in unsightly heaps of waste in low-income areas, compelling residents to seek better, alternative services. This comes on the heels of a situation where there is an abundance of able-bodied, unemployed youth willing to perform the service purely for survival. Thus, the improvement in refuse-collection creates the least social dislocation, and best utilises scarce, skilled labour when it encourages the informal participation of low-opportunity-cost labour.

Additionally, the socio-economic stratification of society and the infrastructural challenges tend to render the HtH system technically impossible in low-income areas, making the use of the *Kaya Bola* the preferred option. This dichotomy is, however fading, because the latter is becoming more professional in its pursuit, and thus more acceptable. For example, in some high-income communities, some residents use the services of the *Kaya Bola*, costing between GH¢1.00 (US\$0,70) and GH¢3,00 (US\$2,04) (depending on the quantity of waste) as a trade-off for the relatively expensive, and inefficient, formal institutional arrangements.⁴⁷

Furthermore, Oteng-Ababio⁴⁸ reveals that between 500 and 700 *Kaya Bolas* operate in the Accra metropolitan area alone. As a livelihood strategy, each waste-picker earns an average of GH¢50,00 (US\$35,10) a day, compared to the current national minimum wage of GH¢3,11 (US\$2,12) – a difference of more than 1 500 per cent. A well-managed informal sector therefore has the potential to ensure sustainable environmental management, and perhaps poverty-alleviation too, through job creation and enhanced economic growth. Yet the informal waste-pickers are treated as an expendable nuisance, and often accused of marring the image of the city. They are frequently ignored within public policy discourse, harassed, and, at times, persecuted.⁴⁹

The Paradox of PPPs

Generally, empirical findings from studies undertaken question the commitment of the authorities in pursuing the policy reform of PPP in SWM. Of paramount importance is the fact that MSWM policy development is in sharp contrast with the tenets of good urban governance. Partnership, in principle, is supposed to be a tripartite enterprise (i.e. with the government as the regulator, the private sector as the service provider and the general public as the consumer or service beneficiary).

Paradoxically, more often than not, the consumer is left out of the equation; such a situation compromises social acceptability and participation. Indeed, local authorities continue to exhibit the conventional public tendencies, where a top-down approach appears to be the norm, as if the opinion of other stakeholders in the decision-making process is irrelevant. In both rich and poor neighbourhoods, residents are not involved in the planning and subsequent implementation of their respective MSWM arrangements, exemplified by the City Country Waste Limited (CCWL) contract of 1997.

The genesis of the CCWL contract, which is the single biggest private contract, dates back to 1997, when CCWL, a Canadian company, supposedly entered into verbal negotiations with Accra Metropolitan Assembly (AMA) to collect, dispose of and manage solid waste within the city for a fee. Coincidentally, around the same period, the (then) government was also negotiating with the Canadian Export Development Corporation (EDC) for a credit facility to purchase waste-service equipment. According to the memorandum of understanding (MOU), the AMA would enter into a financing agreement with the Ministry of Finance for credit of US\$14 630 998 from EDC to purchase the equipment.

Since the AMA did not have the capacity and capability to fully execute the project, it was agreed that the AMA would lease US\$8 382 928 worth of equipment to a reputable company to execute the contract. The remaining amount (US\$6,2m) was

to be used as back-up capital and for subsequent payments to the contractor that would undertake the job. Without recourse to the Assembly procedure of awarding contracts, a seven-year service contract was signed between AMA and CCWL on 4 December 1997. According to the agreement, AMA agreed to pay CCWL a total service fee of US\$30,28 per tonne of solid waste collected, hauled and managed at the landfill site (Table 9.2).

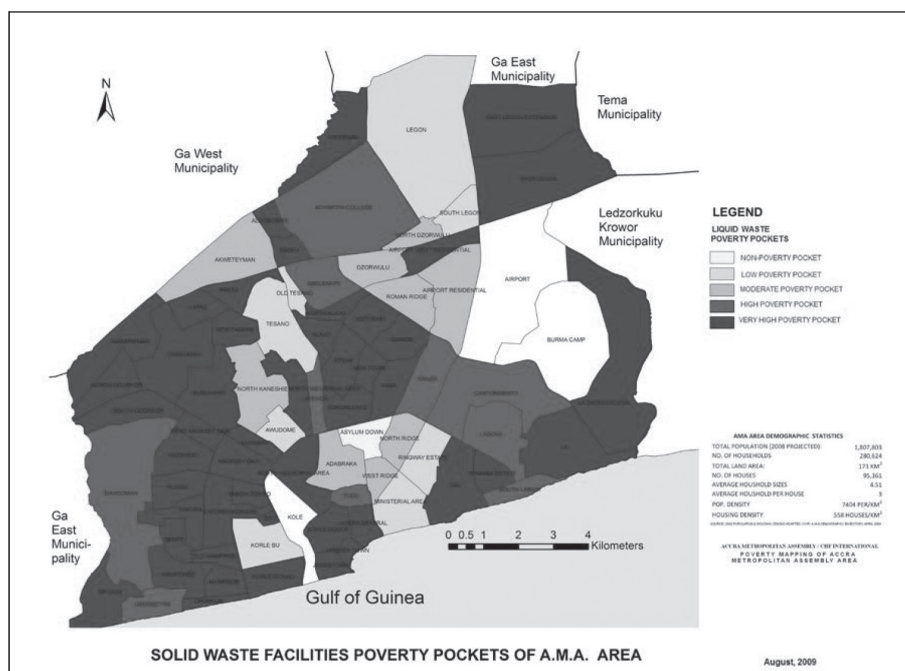
Table 9.2: Prices for collection, haulage and landfill services

Services	Cost per tonne (US\$)
Collection	17.47
Haulage	4.70
Landfill services	8.11
TOTAL	30.28

(Source: AMA/CCWL Service Contract)

Although CCWL was under no obligation to engage the services of other contractors, it sublet several areas to 11 local contractors. The service fee payable by CCWL to the sub-contractors was US\$5,20 per tonne, payable in Ghanaian cedis at the prevailing rate. The analysis of the AMA/CCWL contract brings to the fore certain handicaps that contravene the principles enshrined in the PPP concept, and which have bedevilled many such partnerships in the country. For example, the contract did not follow a competitive bidding process. Indeed, the company was registered on 2 December 1997, with an initial capitalisation of less than US\$5 000. However, two days later, it succeeded in signing a contract worth about US\$10 million, apparently the biggest contract AMA had ever signed with a single private investor.

In principle, there was little financial incentive to the sub-contractors under this arrangement to collect and haul waste. Considering that CCWL at the time was paid US\$22,17 per tonne for collection and haulage, but sub-contracted to local contractors at a price of US\$5,20, payable in cedis, the CCWL made a profit of almost US\$17 for every tonne of waste these sub-contractors collected. The contract also raised questions about conflict of interest and abuse of a government-guaranteed loan, as later revelations showed that the (then) Chief Executive of AMA was a Director of CCWL when the contract was awarded. Currently, AMA spends US\$3,7 million annually for waste haulage alone, and an extra US\$2 million for maintaining the dump-sites.⁵⁰

Figure 9.3: Solid waste facilities poverty pockets in AMA

(Source: Huober, 2010)

Notwithstanding such huge expenditure, studies conducted⁵¹ show that the perception of most residents of environmental sanitation in the national capital is still negative. This is shown in Figure 9.3, which illustrates the solid waste 'poverty pockets' in AMA. From Table 9.3 it can be deduced that the most important rank variable (problem) was that 'containers are not removed in time (always overflowing)'. Thus, the respondents see non-removal of overflowing containers, which leads to putrefaction and the emission of bad odours, as justification for their dissatisfaction with SWM. Furthermore, the untidiness of the containers was raised as a concern. These two issues attest to the fact that the current operation of the CCC system leaves much to be desired.

Table 9.2: Mean ranking and percentile of perception of SWM

Perception of solid waste management	Mean	Std. dev.	Rank Percentiles		
			25th	50th	75th
Containers are not removed in time (always overflowing)	2,72	2,02	1	2	4
Container sites are not kept clean	3,88	2,14	2	3	5

Illegal dumping and littering is not monitored	4,32	2,31	3	4	6
There are no landfill sites in Accra	4,50	2,32	2	5	6
Government has provided only a few sanitation facilities	4,55	1,96	3	5	6
There is no appropriate recycling programme in the country	4,80	1,93	3	5	6
There is no stringent policy or law on solid waste management	5,49	2,36	4	6	8
Ghanaians are hostile towards the environment	5,71	1,95	4	6	7

(Source: Oteng-Ababio, M., 2010a)

The Campsite Model

As already noted, instituting efficient SWM in low-income communities enjoins us to appreciate how outcomes emerge from the confluence of circumstances. It further compels us to measure not only the 'objective' facts, such as the number of days on which waste is collected, or the user fees charged per month, but also 'subjective' meanings of these facts for the individual, such as the level of service satisfaction and convenience, etc. Under the tenets of the current PPP arrangements, the sole responsibility of private contractors operating in the low-income communities is primarily to haul refuse deposited at the CCC collection points to the dump-sites. It is not their responsibility to attract waste to the collection point. This singular defect is seen as a recipe for indiscriminate dumping, especially in areas where, because of limited skips, people have to travel long distances to access the few skips in circulation.

Most researchers unanimously agree that essential urban services are best realised when the so-called unregulated sectors are not administratively and bureaucratically 'crowded out'.⁵² While, in practice, their participation evinces different models with varying characteristics, many can be defined as 'delegated management' approaches.⁵³ Studies⁵⁴ have shown that such models are more sustainable where, firstly, 'contractual arrangements' are well defined and clear about ownership, management and operation; secondly, where service-providers are close to their customers; thirdly, where the system is financially sustainable at affordable prices; fourthly, where there are financial incentives in place to improve performance; and finally, where the regulatory and policy regime is supportive.

Even though the experience of using delegated management for serving the urban poor is not well-developed in Ghana, there is enough evidence to suggest that this gap and the need for a positive policy environment provided a good basis for the

authorities to experiment and engage with it as a way of finding a possible solution to the waste menace in poorer communities, while also responding to poverty concerns. It is in this regard that the author recommends the adoption of a 'camp site model', as an appropriate approach in addressing the protracted waste menace in areas where the majority of the urban population congregate.

Under the proposed approach, places of high waste-generation, such as slums and informal settlements, transport terminals, various stadia and marketplaces are identified, mapped, and segregated. The segregated 'camps' are then contracted out to specific 'service providers', who will be responsible for not only the constant hauling of refuse, but also for general site maintenance, including sweeping, clearing of gutters and occasionally fumigation of the 'camp' to ensure that rodents are kept away, so as to guarantee food-security.

The cost of operating the camp can then, directly or indirectly, be passed on to all those who patronise the services of the camp (beneficiaries) through the institution's daily token fee. In terms of payment, the emphasis is on daily tolls, as attempts to engage the informal sector (i.e. beneficiaries) on monthly contractual agreements could face sustainability crises, since these beneficiaries earn daily income, or wages. For example, the cars/lorries, petty traders, chop-bar and drinking-bar operators, etc., who (over)populate these transport terminals, can be charged as part of the 'token fee' that users pay to access the camp. The model can be replicated in other densely-populated areas, where service-providers (formal and informal) can formalise their activities and employ appropriate technologies to attract waste from every nook and cranny within the camp, so as to ensure a truly clean environment. The tenets of the proposed model resonate with the activities of the 'Great Thinkers Club', a CBO formed in 1999 in Ga-Mashie, Accra, which is involved in waste-collection through the support of CHF International.⁵⁵

Conclusion

This chapter is a beginning of an end; an exploration intended to question a status quo where, in terms of the provision of MSWM services, a few wallow in affluence while the majority live in abject poverty. The impact of such experiences has been extensively documented by prior research.⁵⁶ Recent work has also concluded that one basic necessity of life for human prosperity is maintaining a clean environment; yet no progress has been made in addressing the problems of MSWM in low-income communities, where more than 70 per cent of the urban population live.⁵⁷ These developments provide insight into the mechanism through which the 'camp site model' is introduced and promoted. It provides the theoretical underpinnings to the question of whether or not the informal sector should really 'be seen as a marginalised

“survival” sector, which mops up excess or entrenched workers, or as a vibrant entrepreneur and a part of the economy, which can stimulate economic growth and job creation’.⁵⁸ The studies point to an indispensable informal sector that must be integrated into the formal system, for any kind of sustainable SWM programme to succeed in the future.

Although most desirable, the formalisation of activities into one of positive engagement, support and integration will not happen without challenges; especially when city authorities continue to see informality as a nuisance and illegal, and often erect barriers and other methods to deter participants, including fines and threats of imprisonment. There is also the problem of how to convince the authorities to move away from such traditionally-entrenched policies of repression and neglect of the sector, or informal collusion with it, and to appreciate its environmental and socio-economic importance.

The key metric for a conceptual contribution of the ‘camp site model’ is its usefulness in addressing the MSWM dilemma of where the poorer urban population is most concentrated in an efficient, cost-effective and sustainable fashion. It contradicts the present scenario, in which municipal authorities tend to focus on out-oriented, foreign-inspired policies regarding adaptation of institutional arrangements and the purchase of transportation equipment without any reference to local conditions and expertise. This is particularly important where the literature is replete with cases where such obsession with unregulated cloning of approaches used in more economically developed countries have failed woefully.⁵⁹ This is where the author remains resolute about the prospects of the proposed model, whose goal from its conception and inception has been consilience; that technology must seek tradition. It affords city authorities the opportunity to appreciate things they have previously missed or misinterpreted. This is not to suggest that the model is flawless, or a panacea *par excellence*. Rather, it is hoped that continuous experimentation in different geographical spaces will help shape and reshape the model in tandem with the anticipated progress in economic growth and prospects for all.

Notes and References

- 1 Owusu, G. & Afutu-Kortey, R.L., 2010. Poor urban communities and municipal interface in Ghana: A case study of Accra and Sekondi-Takoradi metropolis. *African Studies Quarterly*, 12(1), pp.1–16; Grant, R. & Oteng-Ababio, M., 2012. Mapping the invisible and real African economy: Urban e-waste circuitry. *Urban Geography*, 33(1), pp.1–21; Melara, A.J.E., Grant, R., Oteng-Ababio, M. & Ayele, B., 2013. Downgrading – an overlooked reality in African cities: Reflections from an indigenous neighborhood of Accra, Ghana. *Applied Geography*, 36, pp.23–30.

- 2 Attahi, K., 1999. Governance and waste management in Abidjan. In A.G. Onibokun (ed.), *Managing the monster: Urban waste and governance in Africa*. Ontario: International Development Research Centre. Available at: <http://www.idrc.ca/publication/onlinebooks> [Accessed 20 November 2006].
- 3 Ojeda-Benitez, S., Armijode-Vega, C. & Ramirez-Barreto, E., 2000. The potential for recycling of household waste: A case study from Mexicali, Mexico. *Environment and Urbanisation*, 12(2), pp.163–73; Adama, O., 2012. Urban governance and spatial inequality in service delivery: A case study of solid waste management in Abuja, Nigeria. *Waste Management Research*, 30(9), pp.991–998.
- 4 Owusu, G., 2008. 'Indigenes' and 'migrants' access to land in peri-urban areas of Ghana's largest city of Accra. *International Development Planning Review*, 30, pp.177–198; Barima, J.O., 2012. Ghana's evolutionary role in a changing world economic order. *International Journal of Technology and Management Research*, 1(2012), pp.37–47.
- 5 GSS (Ghana Statistical Service), 2012. Final report on population and housing census. Accra: Sakoa Press Limited.
- 6 MLGRD (Ministry of Local Government and Rural Development), 2010. *National Environmental Sanitation Strategy and Action Plan (NESSAP) 2010–2015*. Accra: Government of Ghana.
- 7 Mariwah, S., 2012. Institutional arrangements for managing solid waste in the Shama-Ahanta-East Metropolis, Ghana. *Journal of Sustainable Development in Africa*, 14(6), pp.292–312.
- 8 Mensah, A. & Larbi, E., 2005. Well Factsheet – Regional annex. Solid waste disposal in Ghana. *WELL*. Available at: <http://www.lboro.ac.uk/well/resources/fact-sheets/fact-sheets-htm/RSA%20Solid%20waste.html> [Accessed 23 April 2011]; Oteng-Ababio, M., 2012. The role of the informal sector in solid waste management in the GAMA, Ghana: Challenges and opportunities. *Tijdschrift voor Economische en Sociale Geografie*, 103(4), pp.412–425.
- 9 Oteng-Ababio, M., 2007. Private-public partnership in solid waste management in the greater Accra metropolitan area (PhD dissertation). Legon: University of Ghana.; Oteng-Ababio, M., 2012. The role of the informal sector in solid waste management in the GAMA, Ghana: Challenges and opportunities. *Tijdschrift voor Economische en Sociale Geografie*, 103 (4). pp.412–425.
- 10 Asomani-Boateng, R. & Haight, M., 1999. Re-using organic solid waste in urban farming in Africa cities: A challenge to urban planners. Ontario: International Development Research Centre (IDRC); Oteng-Ababio, M., 2012. When necessity begets ingenuity: Scavenging for survival in a globalizing city. *African Studies Quarterly*, 13(1–2), pp.1–21; Melara, A.J.E., Grant, R., Oteng-Ababio, M. & Ayele, B., 2012.
- 11 MLGRD, 2010.
- 12 Ali, A., 2010. Wasting time on solid waste in developing countries. *Waste Management*, 30, pp. 1437–1760; Oteng-Ababio, M., Melara, J.E. & Gabbay, O., 2013. Solid waste management in African cities: Sorting the facts from the fads in Accra, Ghana. *Habitat International*, 39, pp.96–104.
- 13 Medina, M., 1997. The effect of income on municipal solid waste generation rates for countries of varying levels of economic development: A Model. *Journal of Solid Waste Technology & Management*, 24(3), pp.149–155; Oteng-Ababio, M., 2014. Rethinking waste as a resource: insights from a low-income community in Accra, Ghana. *City, Territory and Architecture*, 1(10) pp.1–14.

- 14 Medina, M., 2005. Serving the unserved: Informal refuse collection in Mexican cities. *Waste Management and Research*, 23, pp.390–397; Ahmed, S.A. & Ali, S.M., 2006. People as partners: facilitating people's participation in public-private partnerships for solid waste management. *Habitat International*, 30, pp.781–96; Oteng-Ababio, M., 2012.
- 15 Oteng-Ababio, M., 2007, 2010a, 2012, 2014.
- 16 Huober, A.L., 2010. Moving towards sustainable solid waste management in Accra: Bridging the formal-informal divide (Dissertation). Amherst College, Massachusetts; Ahmed, S.A. & Ali, S.M., 2006; Medina, M., 2005; Post, J. & Obirih-Opareh, N., 2003. Partnerships and the public interest: Assessing the performance of public-private collaboration in solid waste collection in Accra. *Space and Polity*, 7(1), pp.45–63.
- 17 Songsore, J., J. S., Nabila, Yangyuoru, Y., Avle, S., Bosque-Hamilton, E.K. & Amponsah, P.E., 2009. Environmental health watch and disaster monitoring in the greater Accra metropolitan area (GAMA). Accra: Ghana Universities Press.
- 18 Fobil, J.N., Armah, N.A., Hogarh, J.N. & Carboo, D., 2008. The influence of institutions and organisations on urban waste collection systems: An analysis of waste collection system in Accra. *Journal of Environmental Management*, 86, pp.262–271.
- 19 Earth Institute, 2012. Millennium cities initiative AMA community upgrading profile: Korle Gonno. New York: The Earth Institute, Columbia University.
- 20 Oteng-Ababio, M., Melara, J.E. & Gabbay, O., 2013.
- 21 Oteng-Ababio, M., 2007.
- 22 Crook, R. & Ayee, J., 2006. Urban service partnerships, 'street-level bureaucrats' and environmental sanitation in Kumasi and Accra, Ghana: Coping with organisational change in the public bureaucracy. *Development Policy Review*, 24(1), pp.51–73.
- 23 Fobil, J.N., Armah, N.A., Hogarh, J.N. & Carboo, D., 2008.
- 24 Mbuligwe, S.E., 2004. Assessment of performance of solid waste management contractors: A simple techno-social model and its application. *Waste Management*, 24(7), pp.739–749; Mtani, A., 2004. Governance challenges and coalition building among urban environmental stakeholders in Dar es Salaam, Tanzania. *Annals of the New York Academy of Sciences*, 1023, pp.300–307.
- 25 Armah, N.A., 2001. Private sector participation in waste management in Accra: A case study (Unpublished report) Accra: Carl Bro. International; Gwebu, T.D., 2003. Population, development, and waste management in Botswana: Conceptual and policy implications for climate change. *Environmental Management*, 31(3), pp.348–354; Fobil, J.N. & Atuguba, R.A., 2004. Ghana: changing urban environmental ills in slum communities. *International Journal of Environmental Policy and Law*, 34(4–5), pp.206–215.
- 26 Schubeler, P., 1996. Conceptual framework for municipal solid waste management in low-income countries. St. Gallen: SKAT.
- 27 Thompson, I.A., 2008. Domestic waste management strategies in Accra, Ghana and other urban cities in tropical developing nations. Ohio: Case Western Reserve University. Available at: http://www.cwru.edu/med/epidbio/mphp439/Waste_Mgmt_Accra.pdf [Accessed 24 May 2012].
- 28 Fobil, J.N., Armah, N.A., Hogarh, J.N. & Carboo, D., 2008.
- 29 Kendie, S.B., 1999. Do attitudes matter? Waste disposal and wetland degradation in the Cape Coast municipality of Ghana. *Development and Project Planning Centre, Discussion Paper Series*, 2(21).

- 30 Schubeler, P., 1996; Coolidge, G.J., Porter, C.R. & Zhang, Z.J., 1998. Urban environmental services in developing countries. Michigan: Department of Economics, University of Michigan.
- 31 Coolidge, G.J., Porter, C.R. & Zhang, Z.J., 1998.
- 32 Brooke, J., 1992. The secret of a liveable city? It is simplicity itself. The New York Times, 28 May 1992, p.A4.
- 33 Oteng-Ababio, M., 2012.
- 34 UN-Habitat, 2010. State of the world's cities 2010/2011: Bridging the urban divide. London: Earthscan; Visser, M. & Theron, J., 2009. Waste not: Externalisation and the management of waste in Cape Town. Cape Town: Institute for Poverty, Land and Agrarian Studies (PLAAS).
- 35 IBGE (Instituto Brasileiro de Geografia e Estatística), 2010. Resultados preliminares do universo do censo demográfico 2010. Rio de Janeiro: IBGE.
- 36 SLU (Superintendência de Limpeza Urbana), 2008. Annual Report 2008 of the SLU, Belo Horizonte, Brazil. Rio de Janeiro: IBGE.
- 37 Dias, S.M., Ijgosse, J. & Barros, R.T.V., 2010. Belo Horizonte city profile. In UN-Habitat (Ed.), Solid Waste Management in the World's Cities: Water and Sanitation in the World's Cities 2010. New York: UN-Habitat.
- 38 Didero, M., 2012. Cairo's informal waste collectors: a multi-scale and conflict sensitive perspective on sustainable livelihoods. *Erdkunde*, 66(1), pp.27–44.
- 39 Ibid; Neamatalla, M., 1998. *Zabbaleen environment and development program, Cairo, Egypt: The mega-cities project*. New York: Piermont.
- 40 Iskandar, L., 2005. Urban waste managers in Cairo: waste collectors, traders and recyclers. Proceedings of the Tenth International Waste Management and Landfill Symposium. 3–7 October 2005. Sardinia.
- 41 Wilson, D.C., Velis, C. & Cheeseman, C., 2006. Role of informal sector recycling in waste management in developing countries. *Habitat International*, 30, pp.797–808.
- 42 Ibid.
- 43 *Kaya Bolas* or 'truck boys' are porters who carry solid waste from residences, markets and offices (in sacks, baskets, on trucks, etc.) to a container or dumping sites for a fee.
- 44 Coolidge, G.J., Porter, C.R. & Zhang, Z.J., 1998; Post, J. & Obirih-Opareh, N., 2003.
- 45 Oteng-Ababio, M., 2010a. Private sector involvement in solid waste management in Ghana: The case of the Greater Accra Metropolitan Area (GAMA). *Waste Management and Research*, 28, pp.322–329.
- 46 Oteng-Ababio, M., 2010b. Solid waste management in Ghana – beneficiaries' willingness to pay for improved services. *Ghana Geographical Journal*, 2, pp.87–112.
- 47 Oteng-Ababio, M., 2012.
- 48 Wilson, D.C., Velis, C. & Cheeseman, C., 2006.
- 49 AMA (Accra Metropolitan Assembly), 2012. Survey report from MHD, Accra (Unpublished survey report). Accra: AMA.
- 50 Oteng-Ababio, M., 2010a
- 51 Oteng-Ababio, M., 2014.
- 52 Didero, M., 2012.
- 53 See Oteng-Ababio, M., 2014.

- 54 CHF International, 2011. Value chain analysis of solid waste management for youth engagement in service delivery (YES) program in Accra. Accra: CHF International; UN-Habitat, 2010; Oteng-Ababio, M., 2013.
- 55 UN-Habitat, 2013. Time to think urban. Nairobi: United Nations Human Settlements Programme.
- 56 African Union, 2008. Study on the informal sector in Africa. Sixth Ordinary Session of the Labor and Social Affairs Commission of the African Union. 21–25 April 2008. Addis Ababa.
- 57 See Haan, H.C., Coad, A. & Lardinois, I., 1998. Municipal waste management: Involving micro-and small enterprises. Guidelines for Municipal Managers. Turin: International Training Centre of the ILO, SKAT, WASTE. Available at: <http://www.skat-foundation.org/publications/waste.html> [Accessed 26 October 2010]; Medina, M., 2007. *The world's scavengers: Salvaging for sustainable consumption and production*. Lanham: Alta Mira Press.
- 58 Ibid.
- 59 Ibid.

CHAPTER 10

Leading the Way: Direction in Municipal Solid Waste Management in South Africa

Luke Chimuka and Jason Ogola

Introduction

Municipal solid waste (MSW) consists of everyday items we use and then throw away, such as grass clippings, furniture, clothing, product packaging, bottles, food scraps, newspapers, appliances, paint and batteries.¹ It is also commonly known as trash or garbage. This comes from our homes, schools, businesses and hospitals. It is known as MSW, because in many countries of the world, including in South Africa, its collection and disposal falls under the ministry of local government. MSWs are an inevitable part of human activity, and their associated problems can be traced back to the very beginning of civilisation, when humans gathered in communities.² MSWs generated then were contained and disposed of by natural processes. However, as the population increased and villages grew into towns and then into cities, the amount of municipal solid waste generated increased. Even now, the amount of municipal solid waste generated is still rising in response to increasing populations, especially in commercial cities. The current situation is compounded not only by a high urbanisation rate, but also by the changing lifestyles of people who now tend to lean towards a more materialistic society. Currently, half the world's population lives in urban areas, and it is predicted that almost all regions of the world will be predominantly urban by the middle of this century.³ Urbanisation tends to be high in high-consuming countries compared to low-consuming countries.⁴ However, high-consuming countries tend to have better planning and urban waste-management systems than low-consuming countries. In South Africa, two-thirds of the population now lives in urban areas, according to a World Bank survey.⁵ The proportion of people living in urban areas increased from 52 per cent in 1990 to 62 per cent in 2011.⁶ According to a World Bank report, the proportion of people living in rural areas dropped from 48 to 38 per cent over this same period. The study further found that the most rapid growth had taken place in South Africa's smaller cities, such as Polokwane, Rustenburg, Vanderbijlpark, Nelspruit and Ekurhuleni, mostly due to smaller initial populations and increasing economic activity.⁷ Gauteng province, which is the

smallest province by land area, has the biggest and fastest-growing population, with 12,2 million people counted in 2011, a 33,7 per cent increase on 2001.⁸ Overall, South Africa's population grew by 15,5 per cent, or almost seven million people, in the space of 10 years, to reach a total of 51,7 million in 2011, according to the country's latest national census, conducted in that year.⁹ People are still migrating from rural areas to towns and cities in search of jobs and the so-called 'good life'. This has put enormous pressure on service-delivery by local municipalities in terms of solid waste management (SWM).

Any current municipal solid waste management (MSWM) scheme requires planning, and the use of appropriate methods and technology. Further, it is very important that the general population is also brought on board for easy implementation of appropriate methods and technologies in managing MSW. The consequences of poor municipal solid waste management are well-known, and can lead to epidemics.¹⁰ Besides appropriate methods and technology in managing MSW, legislation also plays a critical role. This is very important, because it forces people to change their behaviour regarding the management of MSW.

South Africa did not regard waste management in general as a national priority issue about 19 years ago. The MSWM practices in place before 1994 focused mainly on the end of the waste-management chain. Waste-disposal methods and technologies were emphasised more, which was not in line with international trends in MSWM. The low emphasis accorded to waste-management resulted in waste impacting negatively on the South African environment and on human health. Plastic bags, for example, were a common sight in the South African environment, making cities and towns look dirty and untidy – especially recreation areas, and later rivers. Things began to change in 1999, when the country adopted a National Waste Management Strategy (NWMS).¹¹ This strategy outlines South Africa's goals to address waste management, including those related to MSW. The entire strategy, aimed at improving the quality of the environmental resources affected by uncontrolled and unco-ordinated waste management, is based on the 3R (re-use, reduce, recycle) rule. As South Africa realised the impact of waste on the environment, a policy referred to as the Integrated Pollution and Waste Management Policy (IPWM) of 2000, was established.¹² The policy outlines goals to be achieved through the NWMS of 2001,¹³ and focuses on various key elements of integrated waste-management planning: a waste information system; general waste collection; waste-minimisation; recycling; waste treatment and disposal; capacity-building; and education and awareness. The key objective of the NWMS is to reduce waste generation and the environmental impact of all forms of waste, and to ensure that the health of the people and the quality of the environment are less affected by uncontrolled and unco-ordinated waste management than they have been until now.

Despite the many strides South Africa has made in the management of its MSW, when compared with developed countries, such as those in Western Europe^{14,15} and the USA,¹⁶ it still has some challenges to overcome. Some of these challenges are readily appreciated by looking at the entire current urban MSWM system, and comparing it with that of other countries. What it boils down to is that it is not enough simply to have good legislation and to spend time thinking of appropriate technologies and/or methods to manage MSW. Other factors are also important, such as careful planning and awareness by local municipalities of the entire topic of urban MSWM practices. In order for these strategies to be properly implemented and become successful, the role of communities also needs to be taken into account. Research into urban SWM can also add value to the implementation of the strategies. Composition and the changing patterns of MSW and its generation rates per person, greater willingness on the part of communities to participate in waste-management practices, as well as willingness by population groups in terms of age and gender etc. to participate in waste strategies, can all be determined through research. In some cases, lack of skilled operations staff, apathy at managerial levels, minimal funds, corruption and mismanagement in municipalities are also contributing to poor urban SWM. Some of these problems are more pronounced in rural and semi-rural towns. Such municipalities generally have few middle-class residents who are able to pay for these services, compared to those in cities. This makes them rely heavily on local government funding. For big cities, population increase has worsened the problem, as is the case in South Africa, where informal settlements are expanding exponentially.

Research into Municipal Solid Waste Management

Research into municipal solid waste management is critical, as it has the potential to identify existing gaps and make recommendations on the best options. A number of research studies have been done in this area by various institutions in the country over the years.^{17,18,19,20,21,22,23,24} However, many resources have been channelled into research related to mining waste, which is mostly funded by the Water Research Commission and seen as the most pressing issue at the moment. Very few institutions of higher education are engaged in research related to MSWM. This, perhaps, reflects the very poor or, at best, limited curriculums covering SWM in tertiary education institutions in the country. So far, papers on the topic have been published by institutions such as: the Faculty of Engineering and the Built Environment at Tshwane University of Technology;²⁵ the Centre for Research on Environmental, Coastal and Hydrological Engineering at the University of KwaZulu-Natal;^{26,27} the School of Environmental Sciences at the University of Venda;^{28,29} and the Africa Institute of South Africa.³⁰

Some studies, done at tertiary institutions³¹ and in the private sector,³² can be found on the Internet, but not in scientific journals. Two studies, done by Du Plessis,³³ Ekelund and Nystrom,³⁴ are very important, because they examine composting as one of the solutions to MSWM in South Africa. A study by Ogola et al.³⁵ looked at the management of MSW in South Africa, taking Polokwane as a case study. The study yielded valuable information about the composition of MSW, and the shortcomings of the current management system. Snyman and Vorster³⁶ looked at the current MSWM system in the City of Tshwane, and then suggested appropriate technologies that were assembled into an optimal configuration to achieve a 'zero waste' concept in the City of Tshwane. Matete and Trois³⁷ studied two communities in Durban, and looked at their MSWM, which is disposed of at a landfill. After looking at total waste generated, its composition and the willingness of communities to separate waste into containers; the prices of recyclable materials, etc., a zero-waste scheme, based on costs and landfill airspace savings, was proposed.³⁸ From such studies, it is clear that research into MSWM is very important. Local municipalities, unfortunately, do not seem to recognise the value of research. They seldom partner with institutions of higher learning in order to carry out such research. Therefore, a lot of gaps still exist in MSWM in South Africa that need research. Areas of concern include: the extent to which municipalities are planning to achieve a zero-waste concept; the role composting is playing as an option towards a zero-waste concept; to what extent waste-pickers are organising themselves into co-operatives; and whether any of this has increased their governance and improved performance, etc. Current research on MSWM in international journals seems to be focused on system analysis. This is a discipline that harmonises integrated MSWM strategies and provides inter-disciplinary support for decision-making.³⁹ System engineering models and system assessment tools are chiefly used.⁴⁰

Municipal Solid Waste Management in South Africa and in Comparison to the Developed World

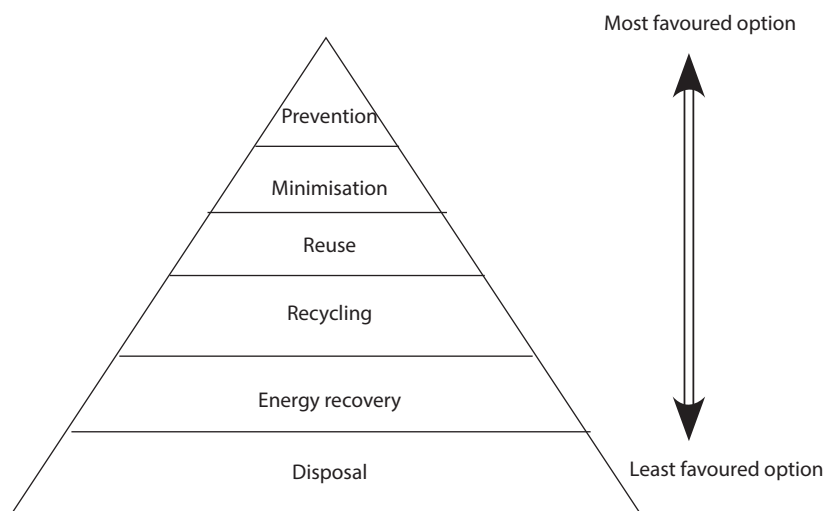
Current Trends in Municipal Solid Waste Management

The waste-management hierarchy shown in Figure 10.1 has been adopted by most industrialised countries as the menu for developing waste-management strategies. It will be seen that prevention, minimisation, re-use and recycling are top priorities, with disposal as a last resort. What is interesting in Figure 10.1 is that composting does not stand alone as a waste-management option. In some cases, it is seen as part of recycling or re-use. Composting is generally more practical in countries that separate MSW at source.⁴¹ According to Seadon,⁴² many programmes have adopted a waste-management hierarchy to address solid waste. For example, New Zealand's

Local Government Act Amendment No. 4 (1996) defines hierarchy as 'reduction, re-use, recycling, recovery, treatment and disposal', with desirability increasing up the hierarchy.

In Singapore, the 3R hierarchy is also based on waste minimisation (reduce, re-use, and recycle – 3R) followed by incineration and landfill. Land is very scarce in this area, and this has resulted in incineration being the preferred method of treatment.⁴³ The United States Environmental Protection Agency⁴⁴ has ranked the most environmentally sound strategies for MSW as: source reduction (including re-use); followed by recycling and composting; and lastly, incineration and/or disposal in landfills.⁴⁵

Figure 10.1: The preferred modern waste management hierarchy

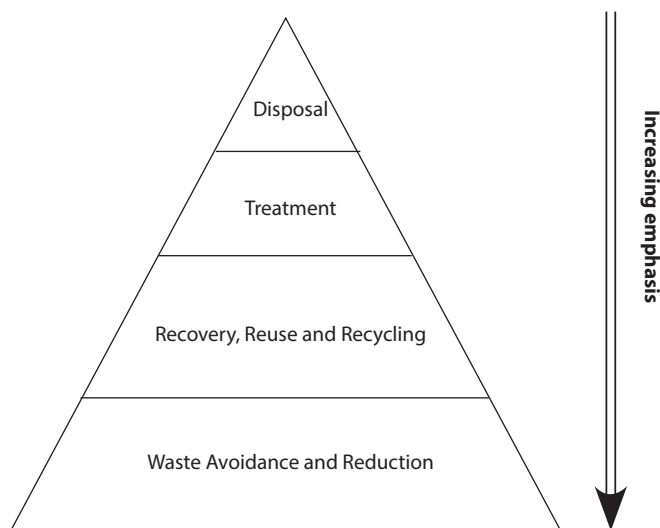


(Source: US EPA 2014, Solid waste and materials management)

Almost all developing countries, including South Africa, have followed a similar MSWM approach to those of the developed world. Recognition of a modern waste-management hierarchy was first introduced into South African waste management policy in the White Paper on Integrated Pollution and Waste Management. This was a hallmark of the 1999 NWMS,⁴⁶ which is represented in Figure 10.2. This is similar to current trends in waste-management, as it groups waste-management measures across the entire value chain in a series of steps, which are applied in descending order of priority. As in Figure 10.1, the foundation of the hierarchy and the first choice of measures in the management of waste is waste avoidance and

reduction, which is the same as prevention. Where waste cannot be avoided, it should be recovered, re-used, recycled and treated. Disposal of waste is seen as a last resort.

Figure 10.2: South African waste hierarchy, 1999



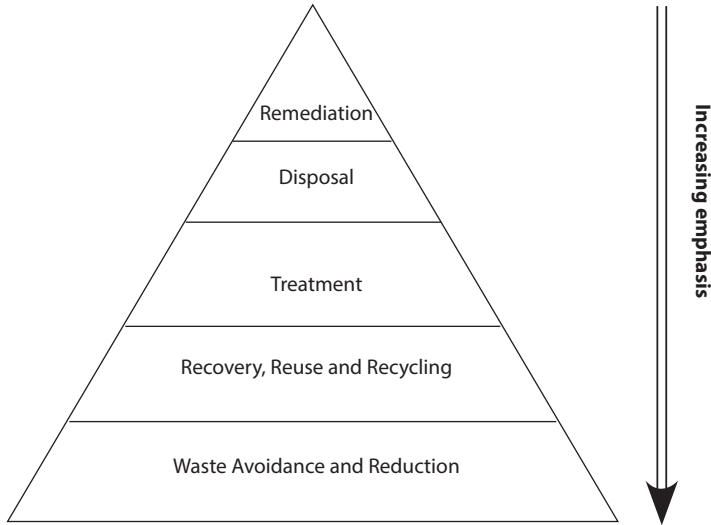
(Source: Adapted from NWMS, 1999)

The draft new NWMS,⁴⁷ which now has been passed into law, addresses those situations in which the waste hierarchy is not implemented successfully, thus disposing of waste with a potential to harm the environment and human health. In such cases, additional measures for the rehabilitation of contaminated land must be put into place. This then provides an additional hierarchy of remediation steps, shown in Figure 10.3.

Implementation of the modern waste hierarchy in any country, including South Africa, requires change in the way products are designed and manufactured, in order to promote their re-use and recycling. This means that all industries involved in the manufacturing of such goods, and even consumers of the goods, should be aware of this hierarchy. Other aspects of NWMS, which are necessary for the implementation of such a hierarchy, are thus important. These include: industry waste-management plans and/or municipal urban solid waste-management plans; categorisation and classification of waste; consumer awareness; responsibility and protection; monitoring and evaluation; and capacity-building.⁴⁸ The NWMS depicted in Figure 10.2 is also referred to as 'cradle-to-cradle' MSWM. This ensures that once a product reaches the end of its life-span its component parts are recovered, re-used or recycled, thereby becoming inputs for new products and materials. This cycle repeats itself until the least possible portion of the original product is eventually disposed of. It

is the opposite of the previous 'cradle to grave' approach, which entailed producer responsibility for the entire life-cycle of a product until its final disposal.

Figure 10.3: South African waste hierarchy, 2010



(Source: Adapted from NWMS, 2010)

Components of Solid Waste Management

Waste Generation and Composition

According to the 1999 State of the Environment Report for South Africa,⁴⁹ the country generates over 42 million cubic metres of solid waste every year. This is about 0,7 kilograms per person per day, compared to 0,73 kg, 0,87 kg and 0,3 kg for the UK, Singapore and Nepal, respectively.⁵⁰ In 2001, the amount of general waste produced throughout South Africa was reported to be increasing annually, due to population growth, economic growth and unsustainable lifestyles. In South Africa, disparities exist in the volumes of waste-generation between higher-income and lower-income groups. In general, the higher-income groups generate more waste per capita (2,7 m³/per capita/annum) than the lower groups (0,2 m³/per capita per annum).⁵¹ This disparity in the generation of MSW between the high-income and low-income groups could also prove challenging in implementing the NWMS, discussed above. Lower-income groups are mostly found in informal settlements, and behavioural or cultural changes to suit the modern waste-management strategy could be difficult.

The State of the Environment Report⁵² compiled for the City of Johannesburg, indicated that the city, with its all regions and its population of 2 982 033, generates a total of 1 560 400 tonnes of waste per annum. There were predictions of this increasing to 1 700 000 tonnes by 2010. Since then, the 2011 census discovered that, despite Gauteng being the smallest province by land area, it has the biggest and fastest-growing population, with 12,2 million people counted in 2011 – a 33,7 per cent increase on 2001.⁵³ This means that the amount of waste generated well exceeded the anticipated 1 700 000 tonnes per annum. The report⁵⁴ further described waste generated in Johannesburg as follows: 23 per cent commercial activities; 10 per cent industrial waste, and 67 per cent from households. This gives a total of 889 665 tons a year, which is 67 per cent of household waste generated, and by 2013 this would have increased to more than 1 079 055 tons a year, based on the economic development growth of the city and its population increase. The lack of current data on the generation of urban MSW in the City of Johannesburg and that of the nation as a whole highlights the need for sustained research in this field. In developed countries such as the USA, such data is compiled on a yearly basis, and it is easy to follow the amount generated per year, its composition, and the various strategies used to manage it.⁵⁵

According to the State of the Environment Report⁵⁶ for the City of Johannesburg, high income-earners currently generate, on average, between 1,3 and 1,6 kilograms of waste per day. Middle income-earners generate between 0,7 and 1,0 kilograms per day, and the lower-income group generates between 0,35 and 0,6 kilograms of waste per day.⁵⁷ These results are consistent with research findings by Ogola et al.⁵⁸ where total household waste generated per day was studied for Polokwane city. In this study, low-income groups were found to generate about 0,32 kilograms of waste per day; middle-income-earners 0,4, and the high-income group about 0,7 kilograms of waste per day. The differences in the amount of waste generated per income group in the two cities reflects both the type of consumption patterns, and the purchasing power of the people. Johannesburg is regarded as the economic hub of South Africa, with people in the city wealthier than their counterparts in smaller cities. This also explains why Johannesburg attracts more people, putting a further burden on urban MSWM. The differences in waste-generation rates per day in various cities in South Africa and among different income groups are common to other developing countries, such as China.⁵⁹ In a study, done by Zhang et al.⁶⁰ on MSW-generation and composition in China, it was found to be non-homogeneous, and varied in different cities. Level of industrialisation and income, consumption habits, etc., were cited as the causes.

Besides understanding the waste-generation rates of each country and its different cities, the composition of the waste generated is also important. Both the amount

of waste generated and its composition are important in terms of planning for any waste-management system. The study conducted by Ogola et al.⁶¹ for Polokwane found that food waste was the highest across all the income groups, with a mean percentage waste-generation of 34 per cent. Garden waste composition was found to be the smallest of all the three income groups, at six per cent. The trend for all the wastes was as follows: food waste (34%)>; paper (20%)>; plastics (18%)>; glass (11%)>; cans (11%)>; and garden waste (6%). Snyman and Vorster reported the percentage composition of MSW for Johannesburg at: (~32%)> organic; (~23% residual)>; (~25% paper>; (~9% plastics>; (~5% glass>; and (~2,5%) metal/cans.⁶² The percentage amounts of organic and residual waste for the City of Johannesburg gives an approximate percentage of organic waste generated, which is close to 52 per cent of the waste generated. Table 10.1 gives a comparison of typical distribution of MSW composition between South Africa and other countries. The variation in composition of the MSW in Table 10.1 can also be attributed to the level of industrialisation and income, consumption habits, etc.⁶³ Low-income and middle-income countries tend to generate a lot more organic waste, in general, than higher-income countries. The high ratio of organic waste in middle-income and low-income countries could be partly linked to a diet in which more unprocessed and unpacked food is eaten than in high-income countries.

Table 10.1: Comparison of typical distribution of MSW composition between South Africa and other countries

Composition (%)	Organic garbage	Paper /Cardboard	Plastic	Glass	Metal	Textile	Wood	Ash	Construction debris	Horticultural waste	Other
RSA*	48,0	22,0	14,0	9,0	7,0	-	-	-	-	-	-
China (2003)a	52,6	6,9	7,3	1,6	0,5	4,7	6,9	19,2	-	-	-
USA (2010)b	27,3	28,5	12,4	4,6	9,0	8,4e	-	-	-	-	3,4
Japan (2000)c	34,0	33,0	13,0	5,0	3,0	-	-	-	-	-	12,0
Canada (2005)c	24,0	47,0	3,0	6,0	13,0	-	-	-	-	-	8,0
France (2005)c	32,0	20,0	9,0	10,0	3,0	-	-	-	-	-	26,0
Germany (2005)c	14,0	34,0	22,0	12,0	5,0	-	-	-	-	-	12,0
Mexico (2005)c	51,0	15,0	6,0	6,0	3,0	-	-	-	-	-	18,0

Portugal (2005) ^c	34,0	21,0	11,0	7,0	4,0	-	-	-	-	-	23,0
Hungary (2005) ^c	29,0	15,0	17,0	2,0	2,0	-	-	-	-	-	35,0
Europe (average) ^a	30,0	32,0	7,0	10,0	8,0	4,0	-	9,0	-	-	-
Low-income countries	40–85	1–10	1–5	1–10	1–5	1–5	-	-	-	-	-
Middle-income countries	20–65	8–30	2–6	1–10	1–5	2–10	-	-	-	-	-
Upper-income countries	6–30	25–66	2–8	4–12	3–13	2–6	-	-	-	-	-

(Source: ^aAdapted from Snyman and Vorster and Ogola et al. 2010; ^bVisvanathan et al. and ^cUSA EPA waste; ^dOECD; ^eTchobanoglous et al.; ^fincludes rubber and leather.)

Waste Collection and Transportation

Waste-collection involves collecting disposed-of MSW from generation points or transfer stations into other waste-management systems, such as recycling, landfill, incineration or composting. Solid waste collection and transportation are often the most costly components of a local waste-management system. This is so in developing countries, including South Africa, where household MSW is collected from each home. The collection system is such that individual households place their daily refuse in a container nearby, whereafter the refuse is collected and delivered to the waste-collection point or disposal site (Figure 10.4). This is contrary to what happens in developed countries, such as Sweden, where, in most cases, households place their waste at nearby centres and it is source-separated.

Population size and density, the area size, the amount of MSW generated, the collection distance, the geometric design of streets and roadways and the level of traffic congestion in the area all have a pronounced impact on the cost of collection and transport of solid waste to landfills. Difficulties in populated areas are pushing disposal facilities further away from waste sources, and increasing the cost of transporting wastes. Transfer stations can potentially reduce the cost of transporting wastes.⁶⁴

A study conducted in Ghana outlined the collection system and design, aimed at significant cost-savings. It focuses on the use of waste containers fitted with

level-sensors and radio communication equipment, which alerts the waste-collector as to the status of each container.⁶⁵ According to a survey conducted in Sri Lanka, 50 per cent of local authorities collect less than two tons of waste per day, and only 24 per cent of households in the Southern Province of Sri Lanka have access to waste collection – as a result of which rural areas have a waste-collection level of less than two per cent.⁶⁶

South Africa faces similar challenges regarding collection of its MSW, just as do many other developing countries. The starting-point to improving the system is source separation of the waste, and the introduction of transfer stations. Transfer stations have the potential to bring down the cost, as collection trucks will not be passing each household. One problem with this approach is that transfer stations could be subjected to vandalism by waste-pickers and even stray dogs, ending up as human and environmental health hazards. But if source separation is part of the municipal management system and waste-pickers are organised into co-operatives, together with local municipalities, they should be able to provide security for such transfer stations.

Figure 10.4: Waste collection in residential areas of Polokwane City



(Source: Ogola et al.)

Waste-Disposal Methods

Landfill is the least-preferred choice for the disposal of waste both for the international and national hierarchy. Many developed countries are therefore trying to reduce the amount of MSW that goes to landfills. In Adelaide in Australia, a combination of composting (eight per cent) and recycling (54 per cent) allows only 38 per cent of the MSW to be landfilled.⁶⁷ In Stockholm, in Sweden, only 10 per cent goes to landfills, because of incineration (59 per cent) and recycling (31 per cent).⁶⁸ In developing countries, including South Africa, a larger percentage of the MSW is still landfilled, and in many cases without any pre-treatment.⁶⁹ For South Africa, this means that

much still needs to be done to encourage other options, such as composting and increased recycling rates, so that the amount of waste that goes to landfill sites is minimised. This is a more feasible and cheaper option than waste-to-energy (WTE) incineration.

Strategies to Improve Urban Municipal Solid Waste Management

Source Reduction

Source reduction, or waste-avoidance and -reduction, involves altering the design, manufacture or use of products and materials, in order to reduce the amount and toxicity of what is thrown away. Source reduction can be a successful method of reducing waste generation. Unlike other strategies downstream of the waste hierarchy, these deal with the root cause of waste generation, and can reduce the amount of waste entering the waste stream. This is especially pertinent for some waste streams where recycling, recovery, treatment or disposal of the waste are problematic. This has been emphasised in the national waste-management strategy.⁷⁰ It is the foundation of the waste hierarchy, and the preferred choice for MSWM systems. However, it requires a change in industry or community behaviour. Practices such as glass-recycling, backyard-composting, two-sided copying of paper and the reduction of transport packaging by industry have yielded substantial benefits in terms of source reduction.⁷¹ For communities, it means that those who can afford it should buy quality, rather than quantity. Make things yourself, especially meals, instead of relying on canned or other fast foods. For those addicted to shopping, take walks with loved ones in a park, rather than in a shopping mall. Stop junk mail/magazines/newspapers from being dropped at home or in your mail box; donate old things rather than just throwing them away. Take your own shopping bag to the shop, and avoid nurturing material wants (a visit to the website www.targetearth.org is recommended). The benefits of source-reduction are many, and include reduced pollutants and greenhouse gas emissions. Energy is saved; resources are conserved; and the need for new landfills and incinerators is reduced.

Developed countries, such as the US and most European countries, have come up with strategies aimed at reducing waste-generation by addressing waste at its source. As an example, more than 55 million tons of MSW was source-reduced in the USA in 2000. This comprised 28 per cent containers and packaging materials, 17 per cent non-durable goods (such as newspapers and clothing), 10 per cent durable goods (appliances, furniture or tyres), 45 per cent 'other' MSW (garden trimmings, food scraps, etc.). More information can be found at www.epa.gov.msw/facts.

For South Africa, source-reduction of MSW at the generation point has perhaps been more visible in certain industries – especially the packaging ones. The most notable of the national government's initiatives with regard to waste-minimisation

has been the plastic bag levy initiative.⁷² This is the first instance of a tax instrument being used to effect change in behaviour at both consumer and industry level.⁷³ This tax instrument managed to reduce the number of plastic bags being disposed of, limit their utilisation, and increase their re-usability and value. Before the plastic bag agreement was introduced in 2003, plastic bags were found in many places, especially in public places, such as recreation centres; most of them were washed into streams and rivers. The plastic bag agreement has now reduced this problem, if not altogether eliminated it. Other initiatives where industries have taken the lead in source-reduction, especially with packaging, can be found on the Packaging Council of South Africa's (PACSA) website (www.pacsa.co.za).

It is difficult to quantify how much source-reduction by the South African public has contributed to reduced urban MSW, except for the plastic bags, which are part of the plastic bag agreement. More research is needed in this area. However, the issue of junk-mail/magazines/newspapers dropped at homes or in mailboxes is one of the major problems that need to be addressed. An energetic 'stop junk-mail/magazines/newspapers being dropped in mail boxes and at homes' campaign is needed. Another debate that is absent on the topic of source-reduction is that of population increase. While the increase in population in developed nations has remained marginal, in developing countries, such as South Africa, the increase is still high. This has a pronounced effect on the amount of waste generated. Therefore, population control should be linked with the ability of governments to deliver basic services, which includes urban municipal solid waste management.

Recycling

Recycling and re-use is aimed at returning the waste to the production cycle. This is now commonplace in both developed and developing nations. It results in a lower environmental impact, and lower energy consumption.⁷⁴ Extraction of virgin raw materials and the amount of waste that is landfilled is decreased.⁷⁵ In general, recycling is more advanced in developed nations than in developing ones, perhaps because legislation was put in place first to regulate it. Systems for recycling, such as source-separation and transfer stations, are also more firmly in place than in developing nations. However, even in developed nations, in some cases, the percentage of recycled materials is not as high as could be expected.⁷⁶ This means that changing behaviour, and not just attitudes, is very important.⁷⁷

The USA's recycling rate for 2010 is shown in Table 10.2. The results show very high and impressive percentages, especially for car batteries, paper, steel and aluminium cans. The average recycling rate for the US (shown in Table 10.2) is about 51,9 per cent. If one takes the average of paper, cans, glass and plastic that is recycled in South Africa, the average recycling rate is about 55,7 per cent. It is

difficult to compare these results with those of other developed nations, due to a lack of data. However, a comparison with other cities, such as Stockholm in Sweden, with a recycling rate of about 31 per cent, and Adelaide in Australia, with a recycling rate of 54 per cent, indicate that the USA's rate is comparable to that of other developed countries, and the USA is, in some cases, doing better.⁷⁸ Stockholm in Sweden is also a special case, as most of its waste is incinerated as part of WTE incineration.⁷⁹

Table 10.2. Recycling rates of selected products in the USA, 2010

Recyclable material	% recycled
Auto batteries	96,2
Newspapers/mechanical papers	71,6
Steel cans	67,0
Yard trimmings	57,5
Aluminium beer and soda cans	49,6
Tyres	35,5
Glass containers	33,4
PET bottles and jars	29,2
HDPE natural (white translucent bottles)	27,5

(Source: Adapted from US EPA)

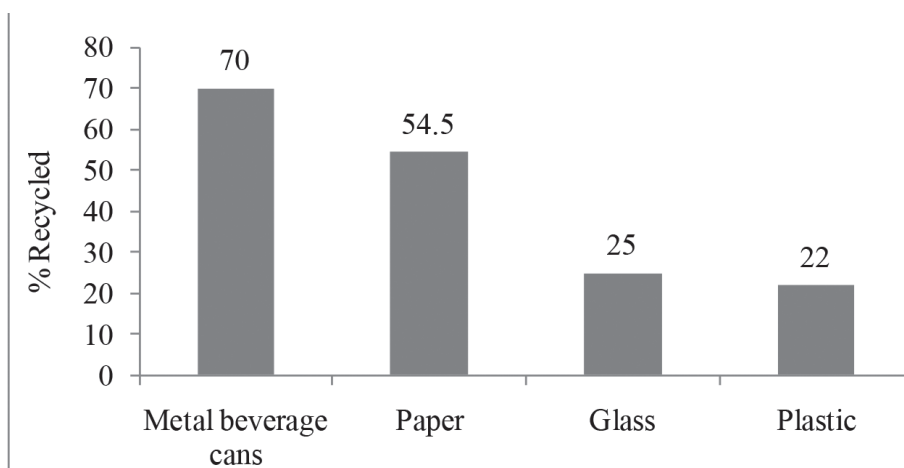
Comparing the USA's recycling data to South Africa's (Table 10.2 and Figure 10.5), one can see that South Africa has, so far, focused mainly on paper, glass, plastic and metal. The average recycling rate for these materials is about 42,9 per cent, which is below the 55,7 per cent for the USA reported in 2010.⁸⁰ A review of MSW for Portugal, by Magarinho et al.,⁸¹ found that 96 per cent of the MSW collected was collected mixed, and only four per cent was separately collected. Of this waste: 68 per cent was disposed of in the landfill; 21 per cent was incinerated at a WTE plant; eight per cent was treated at an organic waste recovery site; and three per cent was delivered for sorting. This suggests that South Africa seems to be doing relatively better, as far as recycling is concerned, than some other developing or similar countries.

Figure 10.6 illustrates that the amount of waste recycled in South Africa has been increasing over the years. This is a similar pattern to the USA's recycling rate. Most of the recycling in South Africa is conducted by the packaging industry.⁸² Companies such as Mondi and Nampak are the major players in the recycling and packaging

industry. Private entrepreneurs and agents of these major recycling companies are involved in the collection and sorting of the waste. In each major town, they have small centres where waste is compacted in bales and transported for recycling. For much smaller towns, waste is collected and transferred to centres where it is compacted. Apart from these major recycling companies and their agents, a good deal of informal collection of recycled material occurs in South Africa. These collectors sell their recovered products to recycling companies or their agents. Scavenging, or informal forms of recycling, mostly takes place at landfills and from households on days just before household bins are collected for landfill. It is estimated that such activities achieve less than a one per cent reduction in the waste stream.^{83,84} Other forms of recycling are drop-off centres used by the general public, which also achieve less than one per cent reduction in the waste stream.⁸⁵ The major problem with the current system is that there is no source-separation of the waste, especially at household level. This means that food waste, newspapers and other categories of waste are contaminated with materials that contain potentially toxic chemicals, such as bulbs, metal cans, etc. If source-separation was in place, the recycling rate could be much higher.

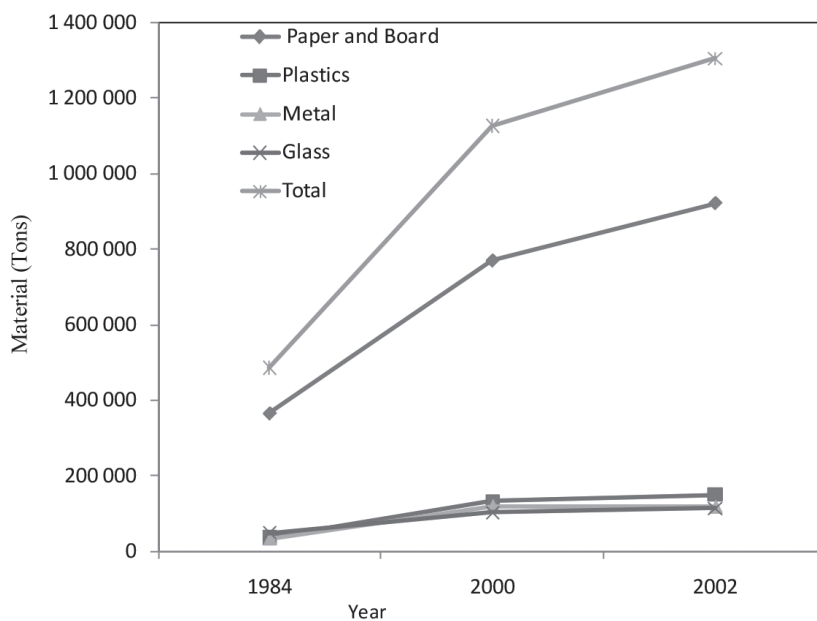
Municipalities, in some cases, have no recycling programmes in place, and things are left in the hands of the private sector and informal waste-pickers. One such example is Polokwane in Limpopo Province, where no recycling programme has been implemented at all.⁸⁶ A study discovered that 60 per cent of waste disposed of in the town's landfill consisted of recyclable waste. Although the municipality does not have a formal waste-recycling system, it was found that the disposal site has informal waste-reclaimers, who are collecting recyclable waste on a daily basis. This has also led to development of an informal settlement close to the landfill. Waste-reclaimers collect all the waste that is re-usable/recyclable, ranging from bricks to plastics, steel, cardboard boxes and cans (Figure 10.7). Interviews were conducted with the waste-reclaimers to get data on the amount of recyclable waste collected each day. Unfortunately they never kept record of the amounts collected, apart from the price per kilogram. For example, plastic earned them 60c/kg; aluminium cans R2/kg; cardboard boxes R30/kg; two-litre plastic cold-drink containers 80c/kg; plastic milk containers 50c/kg, copper R15/kg; and brass R4/kg.⁸⁷ They were able to quantify the amount of money received at the end of the month, which was approximately R300 per person, depending on the rate of collection for each individual. Consultation with the recycling agent that collects waste from the reclaimers reflects that a total of 27 120 kilograms of recyclable waste is collected from the landfill site daily, then sent on a weekly basis to large recycling firms in Gauteng for further processing. This data indicates that waste-claimers, although invisible, should be supported by local municipalities especially, organising them into co-operatives.

Figure 10.5: Recycling rates in South Africa in 2007



(Source: Adapted from NWMS, 2010)

Figure 10.6: Recycling trends for South Africa from 1984–2002



(Source: Adapted from Packing SA)

Figure 10.7: Waste recycling by local waste reclaimers at the landfill site



(Source: Ogola et al.)

Composting

Composting involves the collection of organic waste, such as food left-overs and yard trimmings, and storing it under conditions designed to facilitate its breakdown naturally. The resulting compost can then be used as a natural fertiliser. Composting has always been used as a natural way of disposing of organic municipal solid waste, but in an uncontrolled manner, as it was just thrown onto open dumps and left to decompose. This led to unwanted odours and human health hazards. To get the best quality of compost, one needs to understand the important biological process that takes place. The three most important parameters affecting the composting process are the availability of oxygen, moisture and temperature. Many developed countries, such as the USA, now recognise that composting is part and parcel of the modern MSWM hierarchy (USA EPA), although it does not appear on the hierarchy itself (Figure 10.1). Often, composting is seen as a way of recycling or re-using waste, because the resulting compost is recycled or re-used for a different purpose.

South Africa generally recognises composting as one of the urban municipal strategies. However, its application is still very limited. In a study of MSWM in the City of Tshwane, all organic waste was found to go to the city's four landfill sites.⁸⁸ Garden waste and yard-trimmings are collected by household owners and taken to transfer stations, where municipal or contracted private companies take it to landfills. Food

left-overs, cans, glass, plastics and cardboard are put together in bins, emptied once a week and taken to landfill sites. The opportunity for any composting is thus lost. The mixing of food left-overs with other recyclable materials – especially metal cans – allows contamination by heavy metals.^{89,90} Source-separation of municipal solid waste is therefore very important for composting, and should be included in any waste-management hierarchy. Developed countries that have been successful in composting their organic waste have source-separation as part of the strategy.

Ekelund and Nystrom⁹¹ reviewed the status of composting municipal waste in South Africa. Some of the municipalities where composting was found to take place are Cape Town, Johannesburg, Breede River, Winelands, Makana and Sol Plaatje Municipalities. Thohoyandou Municipality is also known to have community-run compost facilities.⁹² It would be interesting to know the percentage of organic waste that is composted from these facilities. Du Plessis studied the potential for establishing composting facilities at landfill sites in Tshwane, discovering that it is possible to start composting facilities at some of the landfill sites, taking into account the physical, social and operational requirements.⁹³

Energy Recovery from Municipal Solid Waste

Energy-recovery from municipal solid waste is very attractive, because, besides the energy that is generated, the final amount of waste disposed of is much reduced. Many developed nations are now moving towards this as part of the 'zero waste' concept.⁹⁴ Stockholm in Sweden, for example, incinerates 59 per cent of its waste; only 10 per cent goes to landfills, and 31 per cent is recycled.⁹⁵ However, this option requires an investment in technology, and a number of options are available, such as recovery through mass combustion, mechanical processing to separate a fraction of higher caloric value which can be used as solid fuel, extraction and utilisation of landfill gas, anaerobic digestion of the really biodegradable fraction of MSW in a process-digester plant to produce a methane-rich gas, and thermal processing of MSW to generate gaseous or liquid fuel products.⁹⁶

South Africa is aware of the possibility of energy recovery from municipal solid waste, but unlike the international hierarchy on MSWM systems (Figure 10.1), the national one (Figures 10.2 and 10.3) does not include it on the hierarchy. This explains why not much has been reported about it; however, there could be some pilot studies taking place in some regions or municipalities. This option of treating solid waste will soon gain momentum, especially in cities in Gauteng in South Africa, where space for landfill is very limited – unless other options of composting and recycling are significantly improved.⁹⁷

Role of Informal Waste-Pickers

Millions of people in developing countries make a living from sorting, collecting, recycling and selling MSW materials. Many of these are poor people, who have been excluded from the formal job market. Besides the benefits for their communities as a source of income, municipalities and the environment also benefit from such activities. A lot of research has been done concerning waste-pickers,^{98,99,100,101} though not much has been reported for South Africa. Waste-pickers, in the case of South Africa, are recognised as part of the MSWM system. They sort, collect, recycle and sell their waste to recycling companies that have stations in various parts of towns and cities. Some collect the waste from household bins, just before it is collected by municipalities or contractors, and from landfill sites. Some collect it from retailers and wholesalers, but this is mostly cardboard and paper. Recycling companies or sub-contracted companies often collect more from retailers and wholesalers than waste-pickers do.

In South Africa, although waste-pickers are recognised as part of the urban MSWM system, they get very little support from municipalities. Often they work in very poor conditions, with health and injury risks, and they are constantly harassed. Like those who collect from households, they collect into supermarket trolleys and the like, and have to push these to selling centres. This is a big challenge, because most roads have no parallel paths for pedestrians. Because of these problems, although the municipalities recognise them as part of the waste-management system, in reality they are socially invisible, and seldom reported in official statistics. For them to be heard, organising of waste-pickers into some forum is thus critical, and in South Africa they are beginning to do this. The South African waste-pickers' association was born in 2009, when its first meeting was held. Privatisation of MSWM is one the biggest threats to waste-pickers. Formation of co-operatives is one way in which they can have an additional voice.^{102,103} This can help secure government funding, strengthening their infrastructure, governance and training.

Municipal Solid Waste in Informal Settlements

Informal settlements are mostly inhabited by poor people, who produce the least amount of MSW. However, despite this, MSM service-delivery by municipalities is poor in these areas. What makes the situation more difficult is that most informal settlements have no proper roads for pick-up trucks to pass through and collect the waste. Most of the people in informal settlements cannot afford the rates for collection, and they often get free electricity. It is generally impractical to implement any proper waste-management plan, as per the national strategy. The situation is worst in the rainy season, as most of the waste is still being dumped in illegal open dumps and left to decompose. Any MSWM plan for these areas can only work if local

people take their own initiative. The people are generally aware of issues related to waste and the environment, because of the media, but the problem is habit-related.

Future Direction of Municipal Solid Waste Management in South Africa: Towards Zero-Waste Cities

'Zero waste' is a concept aimed at turning current waste-management practices into more efficient and sustainable ones. This means: a 100 per cent recycling rate; recovery of all resources from the waste stream; and producing no harmful waste for the environment.¹⁰⁴ Whereas waste-minimisation focuses on reducing the amount of waste generated, the concept of zero waste goes further.¹⁰⁵ It includes recycling, minimising waste, reducing consumption and ensuring that products are made to be re-used, repaired or recycled back into nature or the marketplace.¹⁰⁶ South Africa generally recognises and accepts the concept of zero-waste cities, and this was part of the so-called 'Polokwane declaration on zero waste by 2022'. This is now seen as the future direction of MSWM in South Africa. Many developed countries, such as Australia and Sweden, are already moving towards zero-waste cities.¹⁰⁷ The Polokwane declaration was based on the urgent need to reduce, re-use and recycle waste, in order to protect the environment and have a waste-management system that promotes effective waste-reduction. The goal of this declaration was to reduce waste generation and disposal by 50 per cent and 25 per cent respectively by 2012, and to develop a zero-waste plan by 2022. The South African Government developed a national waste management strategy to address waste-management aspects, including the zero-waste plans, as envisaged. However, an assessment of current practices in waste management strategies, even in big cities in the country, as reviewed in section 10.3, reveals that it will not be easy to achieve zero waste. Snyman and Voster¹⁰⁸ and Matete and Trois¹⁰⁹ have also looked at the MSWM strategies in two South African cities, and recommend strategies which, in their view, need to be adopted to achieve the zero-waste concept. In the City of Tshwane, it was found that very few minimisation efforts were noticed, and most of the MSW goes into landfill sites and is untreated.¹¹⁰ This is against the ultimate objective of the zero-waste concept, where only a small fraction of the MSW should go to landfill sites. Furthermore, all the waste with potential to cause environmental effects has to be treated prior to landfill disposal. This is not the case in Tshwane.¹¹¹ The study by Matete and Trois¹¹² revealed that an effective source-separation programme, together with organic composting initiatives, would result in an anticipated reduction of in excess of 80 per cent of the MSW stream to be treated downstream. In cities in developed countries, like Stockholm for example, only 10 per cent of MSW goes into

landfill sites.¹¹³ Treatment that includes WTE incineration and recycling plays a very prominent role.¹¹⁴

It is clear that in order for zero-waste cities in South Africa to be realised, a lot of work is still needed. Much of the work lies in the implementation of the national government strategy at the municipal level. Source separation of the MSW from households of high-income and medium-income families should be feasible, but is not done. This should facilitate an increase in composting of organic waste, as well as recycling. High initial investment in source-separation systems could later be realised by increased recycling and composting facilities. Composting is critical, and should be an integral part of any municipal waste-management strategy that hopes to achieve zero-waste status. Composting has the potential to create more jobs among very poor people. Waste-pickers and communities involved in recycling and composting should be encouraged to form co-operatives, so that they can easily access government grants. In order to improve the performance of such co-operatives, experts and academics from universities should be encouraged to be part of the board of such co-operatives, and to offer advice on operations and performance. This could easily broaden the amount of waste currently being composted and recycled at existing facilities, and new ones could be realised in various municipalities.

Educational awareness at family-level needs to be encouraged. This is because household waste is one of the major components of MSW. This should lead to families seeing waste as a resource, and initiating their own source-separation schemes. This has the potential to increase recycling rates, because all recycled products picked by waste-pickers would be of better quality. Educational awareness at the household level has the potential to put pressure on local municipalities, as rate-paying households demand better services from them in terms of waste management. A 'stop junk-mail/magazines/newspapers being dropped in mail boxes and at homes' campaign can only be effective if families are willing to participate in such a programme. Thus, environmental education at family-level is very important. This can also support efforts by schools, especially at primary-school level, where science textbooks feature aspects of environmental education.

Research into MSW by universities, in partnership with local municipalities and non-governmental organisations (NGOs), needs to be encouraged. This has the potential to identify problem areas in implementing strategies leading to zero-waste cities.

Political will is needed among municipal managers to implement strategies leading to zero-waste cities. Where necessary, the government should intervene to apply pressure, so that local governments carry out their mandate on strategies towards zero-waste cities. Municipal managers play an important role, in that they are the engine behind service-delivery at the local level, and as such they should be responsive to private initiatives aimed at improving MSWM.

Political will is also needed to start a debate linking source-reduction and population increase. This debate is not just a South African one, but for all developing countries. As mentioned earlier, while the increase in population in developed nations has remained marginal, in developing countries, such as South Africa, the increase is still high. This has pronounced effects on the amount of waste generated. Therefore population control should be linked with the ability of governments to deliver basic services, which includes MSWM.

Finally, when one compares the management of MSW in South Africa with that of other African countries, it will readily be seen that South Africa is far ahead, because it has developed recycling companies. It has other advantages, because it is more technologically advanced, and in addition it has greater financial resources than most African countries. In other African countries, especially those with poor resources, MSW is still not a priority. Research into MSW is seldom done, but could be – perhaps with the help of donor communities. There is also limited human resource capacity in institutions of higher learning to carry out such studies. However, this should not make South Africa feel relaxed in its management of MSW, as there are still areas of improvement, particularly when compared to developed countries.

Conclusion and Future Perspectives

Through various legislations and availability of the national MSWM hierarchy, together with introduction of waste-management education in primary schools, MSW is now seen as a resource associated with environmental concerns and sustainable development. It is therefore anticipated that, as more communities view waste as a resource and link it to sustainable development, pressure will mount on local municipalities to start implementing systems such as those in developed countries, and particularly the zero-waste concept. Composting, for example, will play a critical role in moving South African cities and towns towards the zero-waste concept. Waste-pickers from household and landfill sites could be major players in composting and recycling, if they become organised into co-operatives. These co-operatives have the potential to come up with their own transfer stations, approved by the local municipality, for easy recycling and composting of household waste. It is also time for South Africa to launch pilot studies on the subject of trying to convert waste into energy. Such studies have the potential to reduce the amount of waste that goes to landfills.

Notes and References

- 1 Zaman, A.U. & Lehmann, S., 2011. Urban growth and waste management optimisation towards zero waste city. *City, Culture and Society*, 2, pp.177–87.

- 2 Magarinho, A., Didelet, F. & Semiao, V., 2006. Municipal solid waste disposal in Portugal. *Waste Management*, 26, pp.1477–89.
- 3 UN-Habitat, 2008. *State of the world cities 2010/2011: Bridging the urban divide*. London: Earthscan.
- 4 Zaman, A.U., & Lehmann, S., 2011.
- 5 South Africa.info, 2013. South Africa 'two-thirds urbanised'. *SAInfo*, [online] 24 January 2013. Available at: <http://www.southafrica.info/news/urbanisation-240113.htm> [Accessed 20 June 2013].
- 6 Ibid.
- 7 Ibid.
- 8 Statistics South Africa, 2011. Census 2011. Pretoria: Statistics South Africa. Available at: http://www.statssa.gov.za/publicatons/SA_statistics/SA_statistics_2011 [Accessed 15 June 2013].
- 9 Ibid.
- 10 Magarinho, A., Didelet, F. & Semiao, V., 2006.
- 11 Department of Environmental Affairs and Tourism. 1999a. *National Waste Management Strategy Action Plans (WMSAP)*. Pretoria: Department of Environmental Affairs and Tourism.
- 12 Department of Environmental Affairs and Tourism., 2000. *White Paper on Integrated Pollution and Waste Management in South Africa*. Pretoria: Department of Environmental Affairs and Tourism.
- 13 Department of Environmental Affairs and Tourism., 2001. *National Waste Management Strategy*. Pretoria: Department of Environmental Affairs and Tourism.
- 14 Zaman, A.U. & Lehmann, S., 2011.
- 15 Pires, A., Martinho, G. & Chang, N., 2011. Solid waste management in European countries: A review of system analysis techniques. *Journal of Environmental Management*, 92; pp.1033–50.
- 16 U.S. Environmental Protection Agency (EPA)., 2014a. Solid waste and materials management. *U.S. EPA*. Available at: www.epa.gov [Accessed 22 July 2014].
- 17 Matete, N. & Trois, C., 2008. Towards zero waste in emerging countries: A South African experience. *Waste Management*, 28, pp.1480–92.
- 18 Nematanga, F., Maringa, S. & Chimuka, L., 2008. Assessment of hospital solid waste management strategies in Limpopo Province, South Africa: a case study of two hospitals. *Waste Management*, 28, pp.1236–45.
- 19 Godfrey, L., 2008. Facilitating the improved management of waste in South Africa through a national waste information system. *Waste Management*, 28, pp.1660–71.
- 20 Ogola, J.S., Chimuka, L. & Tshivhase, S., 2010. Management of municipal solid wastes: A case study in Limpopo Province, South Africa. *Waste Management*, 1, pp.91–112.
- 21 Trois, C. & Simelane, O.T., 2010. Implementing separate waste collection and mechanical biological waste treatment in South Africa: A comparison with Austria and England. *Waste Management*, 30, pp.1457–63.
- 22 Nahman, A. & Godfrey, L., 2010. Economic instruments for solid waste management in South Africa: Opportunities and constraints. *Resources, Conservation and Recycling*, 54, pp.521–31.
- 23 Snyman, J. & Vorster, K., 2010. Towards zero waste: A case study in the city of Tshwane. *Waste Management and Research*, 29, pp.512–20.

- 24 Simelane, T. & Mohee, T., 2012. *Future directions of municipal solid waste management in Africa (Policy brief)*. Pretoria: Africa Institute for South Africa.
- 25 Snyman, J. & Vorster, K., 2010.
- 26 Matete, N. & Trois, C., 2008.
- 27 Trois, C. & Simelane, O.T., 2010.
- 28 Nematanga, F., Maringa, S. & Chimuka, L., 2008.
- 29 Ogola, J.S., Chimuka, L. & Tshivhase, S., 2010.
- 30 Simelane, T. & Mohee, T., 2012.
- 31 Du Plessis, R., 2010. *Establishment of composting facilities on landfill sites* (MSc dissertation). Pretoria: University of South Africa.
- 32 Ekelund, L. & Nystrom, L., 2007. *Composting of municipal in South Africa: Sustainability aspects* (MSc dissertation). Uppsala: Uppsala University. Available at: http://www.utn.uu.se/sts/cms/filarea/0602_kristinanystromlottenekelund.pdf [Accessed 22 July 2014].
- 33 Du Plessis, R., 2010.
- 34 Ekelund, L. & Nystrom, L., 2007.
- 35 Ogola, J.S., Chimuka, L. & Tshivhase, S., 2010.
- 36 Snyman, J. & Vorster, K., 2010.
- 37 Matete, N., & Trois, C., 2008.
- 38 Ibid.
- 39 Pires, A., Martinho, G. & Chang, N., 2011.
- 40 Ibid.
- 41 Richard, T.L. & Woodbury, P.B., 1992. The impact of separation on heavy metal contaminants in municipal solid waste compost. *Biomass and Bioenergy*, 3, pp.195–211.
- 42 Seadon, J.K., 2006. Integrated Waste Management – Looking Beyond the Solid Waste Horizon. *Waste Management*, 26, pp.1327–36.
- 43 Bai, R. & Suntato, M., 2001. The practice and challenges of solid waste management in Singapore. *Waste Management*, 22, pp.557–67.
- 44 U.S. EPA., 2014a.
- 45 Ibid.
- 46 Department of Environmental Affairs and Tourism., 1999a.
- 47 Ibid.
- 48 Ibid.
- 49 Department of Environmental Affairs and Tourism., 1999b., *The State of the Environment Report for South Africa*. Pretoria: Department of Environment and Tourism.
- 50 Ibid.
- 51 Ibid.
- 52 SRK Consulting., 2003. *City of Johannesburg State of Environmental Report 2003*. Johannesburg: Ekurhuleni Metropolitan Municipality.
- 53 Statistics South Africa., 2011.
- 54 SRK Consulting., 2003.
- 55 U.S. EPA. 2014b, Non-hazardous waste. U.S. EPA. Available at: <http://www.epa.gov/ep-awaste/nonhaz/municipal/index/htm> [Accessed 22 July 2014].
- 56 SRK Consulting., 2003.
- 57 Ibid.
- 58 Ogola, J.S., Chimuka, L. & Tshivhase, S., 2010.

- 59 Zhang, D.Q., Tan, S.K. & Gerseberg, R.M., 2010. Municipal solid waste management in China: Status, problems and challenges. *Journal of Environmental Management*, 91, pp.1623–31.
- 60 Ibid.
- 61 Ogola, J.S., Chimuka, L. & Tshivhase, S., 2010.
- 62 Snyman, J. & Vorster, K., 2010.
- 63 Zhang, D.Q., Tan, S.K. & Gerseberg, R.M., 2010.
- 64 Koushk, P.A., Al-Duaij, U. & Al-Ghimlas, W., 2004. Collection and transportation cost of household solid waste in Kuwait. *Waste Management*, 24, pp.957–64.
- 65 Amponsah, S.K. & Salhi, S., 2004. The investigation of a class of capacitated arc routing problems: The collection of garbage in developing countries. *Waste Management*, 34, pp.711–21.
- 66 UN-Habitat., 2008.
- 67 Zaman, A.U., & Lehmann, S., 2011.
- 68 Ibid.
- 69 Snyman, J. & Vorster, K., 2010.
- 70 Department of Environmental Affairs and Tourism., 2010.
- 71 Ibid.
- 72 Ibid.
- 73 Ibid.
- 74 Sharholly, M., Ahmad, K., Mahmood, G. & Trivedi, R.C., 2008. Municipal solid waste management in Indian cities: A review. *Waste Management*, 28, pp.459–67.
- 75 Ibid.
- 76 Gonzalez-Torre, P.L., Adenso-Diaz, B. & Ruiz-Torres, A., 2003. Some comparative factors regarding recycling collection systems in regions of USA and Europe. *Journal of Environmental Management*, 69, pp.129–38.
- 77 Ibid.
- 78 Zaman, A.U., & Lehmann, S., 2011.
- 79 Ibid.
- 80 Ibid.
- 81 Matete, N., & Trois, C., 2008.
- 82 Ibid.
- 83 Des Ligneris, J., 2000. *Composting*. Biennial Conference and Exhibition. 5–7 September 2000. Somerset West, Cape Town.
- 84 Ridl, J., 2003. *Environmental law: A student guide*. Durban: University of Natal.
- 85 Ibid; Des Ligneris, J., 2000.
- 86 Ogola, J.S., Chimuka, L. & Tshivhase, S., 2010.
- 87 Ibid.
- 88 Snyman, J. & Vorster, K., 2010.
- 89 Richard, T.L. & Woodbury, P.B., 1992.
- 90 Chimuka, L. & Manungufala, T.E., 2009. Sources, bioavailability and the fate of heavy metals and organic contaminants in compost manure. *Dynamic soil, Dynamic Plant*, 3(1), pp.32–8.
- 91 Ekelund, L. & Nystrom, L., 2007.
- 92 Manungufala, T.E., Chimuka, L. & Maswanganyi, B.X., 2008. Evaluating the quality of communities-made compost manure in South Africa: A case study of content and sources

- of metals in compost manure from Thulamela Municipality, Limpopo Province. *Bioresource Technology*, 99, pp.1491–6.
- 93 Du Plessis, R., 2010.
- 94 Zaman, A.U., & Lehmann, S., 2011.
- 95 Ibid.
- 96 Dent, C.G. & Krol, A.A., 1990. Municipal solid waste conversion to energy. *Biomass*, 22, pp.307–27.
- 97 Matete, N. & Trois, C., 2008.
- 98 Wilson, D.C., Velis, C. & Cheeseman, C., 2006. Role of informal sector recycling in waste management in developing countries. *Habitat International*, 30, pp.797–808.
- 99 Paul, J.G., Arce-Jaque, J., Ravena, N. & Villamor, S.P., 2012. Integration of the informal sector into municipal solid waste management in the Philippines. What does it need? *Waste Management*, 32, pp.2018–28.
- 100 Sasaki, S. & Araki, T., 2013. Employer-employee and buyer-seller relationships among waste pickers at final disposal site in informal recycling: The case of Bantar Gebang in Indonesia. *Habitat International*, 40, pp.51–7.
- 101 Tirado-Soto, M.M. & Zamberlan, F.L., 2013. Networks of recyclable material waste pickers' cooperatives: An alternative for solid waste management in the city of Rio de Janeiro. *Waste Management*, 33, pp.1004–12.
- 102 Wilson, D.C., Velis, C. & Cheeseman, C., 2006.
- 103 Tirado-Soto, M.M. & Zamberlan, F.L., 2013.
- 104 Zaman, A.U., & Lehmann, S., 2011.
- 105 Matete, N., & Trois, C., 2008.
- 106 Ibid.
- 107 Zaman, A.U., & Lehmann, S., 2011.
- 108 Snyman, J. & Vorster, K., 2010.
- 109 Matete, N., & Trois, C., 2008.
- 110 Snyman, J. & Vorster, K., 2010.
- 111 Ibid.
- 112 Matete, N., & Trois, C., 2008.
- 113 Zaman, A.U. & Lehmann, S., 2011.
- 114 Ibid.

CHAPTER 11

Innovations in Municipal Solid Waste Management: Experiences from eThekweni Municipality, South Africa

Trynos Gumbo and Thokozani Simelane

Introduction and Background

World cities have, over the past several decades, been experiencing wide-ranging and sustained advances in production processes, as well as improvement in consumption and standards of living. Related to these developments has been the rise in population, giving rise in turn to new challenges. Among them is increased solid waste (SW) generation. The African continent, just like other developing continents, such as Latin America and Asia, has been greatly affected by rapid urban population growth, particularly during the nineteenth century, causing unprecedented demand on municipalities to provide services such as waste collection, transportation, treatment and disposal.¹ These sentiments are echoed by various scholars, who posit that African cities have continued to experience rapid growth, both physical and demographic, which can be directly linked to modernisation and globalisation processes. This has placed many local authorities under immense pressure to provide an efficient and effective waste-collection service.^{2,3}

Paradoxically, local authorities in most developing countries, which have traditionally been at the centre of managing SW in their jurisdictions, have repeatedly demonstrated a lack of capacity to effectively meet the demand for efficient and proper disposal of waste.⁴ It is therefore imperative that municipalities devise and formulate programmes, strategies and approaches to achieve sustainable solutions to these myriad challenges, as they demand concerted effort from a multiplicity of stakeholders, which can only be achieved through collaboration and innovation.⁵ Using the eThekweni Municipality as the subject of the study, this chapter presents innovations that have been put forward on the African continent to improve municipal solid waste (MSW) management. Drawing from lessons and practices in developed countries, the study was conducted as a response to appeals for comprehensive empirical research on best practice, which could inform future interventions in MSW management, and the alternative use of waste as a resource.⁶ The over-arching

mission of the study was to investigate innovations that have been developed to promote clean and healthy urban environments, and the recovery of waste through the generation of renewable energy sources, which in eThekwin Municipality include gas, heat and electricity derived from MSW. The field studies generated large quantities of data on cutting-edge, innovative ways of managing MSW and renewable energy production from MSW. Specifically, the study sought to generate data that would help us to understand the programmes and projects that have been formulated to improve MSW management in eThekwin Municipality, the processes and stages of energy-recovery from waste, and the challenges faced and possible solutions that can be employed to improve the situation. The chapter specifically focuses on the experiences of waste reduction, collection, transportation, disposal and treatment.

The eThekwin Municipality is one of the metropolitan cities in South Africa. It was the first city in the country and on the African continent to recover energy from MSW through the adoption of appropriate technologies to generate renewable energy from waste: the so-called waste-to-energy (WTE) projects.⁷ Besides improving MSW management and ensuring healthy urban environments, such innovations have helped to supplement and diversify energy supplies and, in this regard, are renewable sources that assist in meeting the immediate and long-term needs of ever-increasing populations.⁸ The chapter goes on to discuss the prospects of adopting and implementing the same innovations in managing MSW in other African countries. It is expected that the chapter will aid in understanding the conservation and management of urban environments, to ensure their habitability and cleanliness. Knowledge concerning ways of improving and diversifying the energy-supply sources of the continent, through the adoption and use of green energy sources, is expected to be generated. The chapter ends by offering recommendations on the way forward, as the continent steers towards healthy urban environments and a 'green revolution' agenda.

Research Methodology

To shape the research processes and gather essential and adequate data in terms of both quality and quantity, a phenomenological case-study design and a mixed-method research approach were adopted.⁹ Leedy and Ormrod assert that multi-disciplinary and mixed-method research paradigms facilitate the gathering of assorted data. In this case, three sets of quantitative, qualitative and spatial data,¹⁰ which were collected, were pertinent in understanding the phenomenon. Babbie and Mouton offer case-study research designs and approaches that assist in identifying the target population, data collection, analysis, interpretation and reporting of developmental activities and processes.¹¹ This study therefore involved an orderly investigation of

MSW management in eThekweni Municipality to provide a detailed exploration, explanation and description of the phenomenon.

Sampling and Data-Collection Techniques

Stratification of MSW sources, according to general town-planning land uses – which include residential, commercial and industrial as well as markets – was done to avoid missing some interesting and important cases in the study.¹² SW collection points, such as skips, bunkers and open spaces, were also selected randomly for the study. Purposive and snowballing sampling methods were used to identify key informants involved with SW collection, transportation, disposal and treatment within the municipality. Officials at tertiary educational institutions, non-governmental organisations (NGOs), private-sector organisations and community-based organisations were also targeted, to make up a pool of knowledgeable key informants who are actively involved in MSW management and research.¹³ Both secondary and primary data sets were used to complement each other, thus providing interfaces of theory and practice and helping to extend debate and discourse around the methods that can be employed to improve MSW management systems.

First, a comprehensive and intensive review of literature was done to generate distilled theoretical frameworks essential in MSW management, including initiatives and innovations that are already commonly applied. Second, primary data was largely gathered through interviews with key informants, who are officials working in the SWM departments of the municipality, and other relevant organisations.¹⁴ Observations of the phenomenon and photographic surveys are also primary data-collection methods, which were used to generate fresh data from the field, particularly to reveal any innovations and initiatives at collection sites, recycling sites, landfill sites, energy-processing plants and operational centres. To sum up, the fieldwork targeted all those involved in formulating and implementing policies on MSW management throughout the various stages of collecting, recycling, recovery and disposal of waste. The battery of data-collection methods, sources and the anticipated outcomes of the research are summarised in Table 11.1.

Table 11.1: Research methodology matrix

Objective	Activities, methods and sources	Deliverables
1. To describe the initiatives (including programmes and strategies) being used to improve MSW management in the eThekwin Municipality.	Literature search, document analysis and interviews with ministerial and departmental officials, tertiary educational institutions, private-sector participants, community-based organisations (CBOs), individuals and other stakeholders.	Distilled information on programmes, policies, strategies and legislative instruments in improving MSW management systems.
2. To examine the innovations that include the processes and stages employed in converting MSW into innovative energy sources by generating landfill gas, electricity and heat-energy sources within the two cities.	Visiting and conducting photographic surveys, as well as discussions on landfill, dumping-sites and MSW processing sites, such as the La Mercy, Marianhill and Bisasar landfill sites.	Innovations in the various processes and methods applied in MSW treatment for purpose of generating gas, electricity and heat-energy sources within the two cities.
3. To identify the challenges being faced in converting MSW to energy, and the possible solutions that could be employed to improve the generation of energy from waste.	Interviews, discussions and photographic surveys of sites and plants.	Challenges commonly faced and possible solutions to the problems.

(Source: Developed by Authors, 2013)

Thirdly and finally, both qualitative and quantitative data gathered from the field were analysed, mainly using content analysis, Excel and appropriate spatial software packages. Theoretical explanations, statistical information and maps were used to represent the state of MSW management in the municipality. The new findings were used to refine understanding of the phenomenon, thus contributing to the development of new theoretical frameworks and representations that advance and explain developments and aid in the understanding of appropriate initiatives and innovations in MSW management.

Conceptualising Municipal Solid Waste Management

Rubbish, or garbage, as MSW is generally known, comprises food leftovers, garden waste, paper, plastic, glass and metal that can be generated from a variety of sources, such as households, commercial activities and markets, as well as minor

contributors, such as street-sweepings, construction and demolition debris.¹⁵ The components of MSW are influenced by a number of factors, including the level of economic development, living standards and life-styles, and it has generally been noted that developing countries on continents such as Africa, Asia and Latin-America generate MSW with a higher biodegradable content than that found in the developed world.¹⁶ It is the organic component of the MSW that is essential in generating renewable energy through incineration or landfilling the waste first, while the non-organic matter can be recycled and reused or, if of no value, buried underground to promote environmentally healthy urban centres. The maintenance of hygiene and cleanliness in urban communities involves several stages of MSW management, including collection, transfer, treatment, recycling, resource-recovery and disposal.¹⁷ As part of fulfilling the traditional roles and responsibilities of maintaining the cleanliness of their areas of jurisdiction, municipalities have always single-handedly collected, transported, treated and disposed of MSW. The complex and integrated processes of managing MSW range from eco-design of production plants to reducing waste at source, re-using, recycling and recovery of waste generated, as well as composting, incineration and landfilling of collected waste from various sources.¹⁸ Disposal at landfill sites can be done directly from source, or from temporary community collection points, such as skips, bunkers, standby trailers and open lots, while collection may be done at sources where the MSW is directly disposed of at final destinations (which are normally landfill sites). The waste can be gathered at centralised collection points, such as skips, bunkers, standby trailers and open lots, before it is transferred to landfill sites.

The integrated management of MSW in cities demands a multiplicity of players and complex processes, making it imperative to adopt and apply the collaborative planning theoretical framework in an attempt to understand the various components involved. The collaborative planning theory is built on the process of bringing together all relevant participants to work towards shared goals and innovative approaches when faced with mammoth and challenging issues.¹⁹ Innes & Booher posit that a collaborative planning approach promotes consensus among relevant stakeholders, who agree to strategies that contribute to problem-solving as they pool their experiences, resources, methods and ideas.²⁰ This view is supported by Kumar & Paddison, who contend that to attain common goals, participants willingly work together in the process, sharing responsibilities in various scenarios.²¹ Emphasis is placed on the greater picture, rather than on individual success and benefit; however issues of existing and entrenched power structures should be obviated, as they impact on the processes.²² The collaborative planning framework suggests that stakeholders adapt their plans and actions to relate these to each other, in order to achieve common goals.²³ In complex, diverse and inter-dependent environments, such as MSWM and the conversion

of waste to energy, collaborative planning promotes satisfactory results. Besides, the theoretical framework can be used to integrate the institutions involved in some activities, as well as their practices.²⁴ Seminal work by Healey on collaborative planning revealed that urban contexts are theatres of complex, multiple and interactive social, economic and environmental activities that need to be harmonised and pro-actively planned. It has also been repeatedly observed that there is a need to conscientise, educate and train the public in MSWM in the quest to improve solid waste disposal.²⁵ The framework helps to improve understanding and actions required in the conversion of MSW to energy sources within urban centres on the African continent.²⁶ Building common understanding among stakeholders results in significant achievements; for example, the private sector may partner with local authorities in generating essential benefits from MSW.²⁷

Innovations in Municipal Solid Waste Management: The Case of eThekweni Municipality

eThekweni is one of the more progressive metropolitan cities in South Africa. As a country, South Africa is not only progressive politically and socially, but it is also currently the economic power-house on the African continent, which is home to a population of about 50 million.^{28,29} Just like any other developing country, South Africa is facing serious challenges with MSWM in almost all of its urban centres and, as a result, the metropolitan cities have been adopting innovative SWM strategies to improve the situation. A case in point is the eThekweni municipality, which embraced innovative technologies to convert solid waste into energy at the turn of the millennium. The municipality was the first city council, not only in South Africa, but also on the continent, to initiate and implement a landfill gas-to-electricity project.

The idea that the municipality should generate energy from MSW was mooted in 2002, further refined in 2003, and finalised in 2004 when the World Bank agreed to support the project due to its potential for the reduction of emissions in the atmosphere. Actual generation of electricity from waste began in 2006. Although WTE technologies had long been adopted in the developed world, particularly in the United States and in Western European countries such as Germany and the United Kingdom, it was not too late for the Department of Cleansing and Solid Waste of the eThekweni Municipality to adopt the same modern systems three decades later. For almost a decade now, the municipality has demonstrated to the continent and the world at large that it is perfectly possible for African cities to achieve the twin objectives of: generating clean, renewable energy sources that contribute to economic development; and at the same time reduce the urban social and environmental problems associated with improper disposal of waste, which is a common blot on the African city-landscape.

Innovations for Disposal and Treatment of Municipal Solid Waste

The municipality has invested massively in developing state-of-the-art, well-designed and engineered MSW disposal sites, transforming dump-sites into modern landfill sites, while closing some small-scale and unhygienic dump-sites. At the turn of the new millennium, the municipality also initiated work to treat disposed MSW on three landfill sites, i.e. La Mercy, Mariannhill and Bisasar, under the Clean Development Mechanism (CDM), a brainchild of the United Nations Framework Convention for Climate Change (UNFCCC) of the Kyoto Protocol.⁵⁰ Details of the current state of the landfill sites are provided in Table 11.2.

Table 11.2: Landfill sites in eThekweni municipality

Name of landfill	Size of landfill	Starting year	Ending year	Deposit rate/day	Weigh-bridge	Gas capture	Electricity generation	Recycling activities	Leachate treatment
La Mercy	7,2 ha	1980	2006		-	-	-	-	-
Marian-hill	18,5 ha	1997	2022	700 tons	Yes	Yes	1 MW	Yes	Yes
Bisasar Road	44 ha	1980	2013	3000 tons	Yes	Yes	6,5 MW	Yes	No
Buffels-draai	100 ha	2006	2076	450 tons	Yes	No	No	No	Yes

(Source: Compiled by Authors from field studies, 2013)

Currently only two landfill sites are treating MSW to produce electricity from gas, while two have leachate-treatment plants that purify waste water. The landfill gas-to-electricity project at La Mercy was abandoned due to low levels of gas being obtained, while the Buffelsdraai landfill is yet to commence electricity generation, as it is still undergoing expansion.

Innovations at Mariannhill Landfill Site

Cutting-edge innovations in the management and treatment of MSW that were adopted and implemented by the municipality have gone a long way to promote the collection, transportation and disposal of waste, making the city environmentally clean. At Marianhill, landfill gas is captured and about one megawatt (MW) of electricity is generated. There is also a sequencing batch reactor for the treatment of leachate, and a registered conservancy area – the first of its kind on the African continent. The one MW of power is stepped up by a transformer and fed into the 11 KV line that is connected to the eThekweni municipal grid. The Marianhill landfill site has largely contributed to the improvement of MSW collection, transportation, disposal and treatment, as well as conservation of the environment within and surrounding the dump-site.

Figure 11.1: Landfill gas to electricity and recycling projects at Marianhill site



(Source: Authors 2013)

Marianhill has a well-managed landfill gas-to-electricity site and recycling project, which has substantially improved MSW management in the municipality.

Innovations at Bisasar Road Landfill Site

The Bisasar Road landfill site is located close to the main commercial and residential zones of the municipality, and as a result it receives about 3 000 tonnes of waste per day, which is about a million tonnes a year. Overall, it has a capacity of about 21 million cubic metres of waste. The 6,5 MW of electricity it generates has contributed markedly to the alleviation of electricity shortages in the city and the reduction of greenhouse gases (GHGs) from coal-fired power stations, resulting in improved air quality in nearby communities. The landfill site also has a recycling project that has helped to improve the collection and disposal of MSW within the municipality.

Figure 11.2: Landfill gas-to-electricity and recycling projects at Bisasar Road landfill site



(Source: Authors, 2013)

Bisasar landfill site has smoothly-functioning and well-managed landfill gas-to-electricity and recycling projects. Figure 11.2 shows well-co-ordinated recycling activities at the landfill.

Innovations at Buffelsdraai Landfill Site

The recently-developed Buffelsdraai site began receiving waste in 2006. It is 100 hectares in extent, and is expected to last for about 70 years. It is well-engineered and designed, with extensive extensions taking place to prepare for future disposal and treatment of waste at the site. Figure 11.3 shows the state-of-the-art waste-weigh-bridge and the leachate treatment plant at the landfill site.

Figure 11.3: Waste weigh-bridge and leachate treatment plant at Buffelsdraai Road landfill site



(Source: Authors, 2013)

The landfill site currently receives and processes about 450 tonnes of general municipal waste daily, but is expected to receive about 2 000 tonnes per day once the Bisasar landfill site closes. The landfill site has a leachate plant with the capacity to process 200m³ of waste water from the landfill. It is, however, currently processing only 110m³ of leachate, since it is receiving very low quantities of waste. Massive construction works are taking place to set up more cells and lay pipes for gas and waste-water drainage, thereby creating capacity for more waste-disposal and treatment in the near future.

Innovations in the Transportation of Municipal Solid Waste

The municipality has made great strides in improving and maintaining the fleet of vehicles used to transport waste from sources such as households, streets and commercial undertakings. There is a vibrant, well-equipped and -resourced department that is solely meant for the transportation and disposal of MSW within the

municipality. Vehicles are regularly serviced and replaced as required to ensure efficiency and effectiveness. A vehicle service and replacement plan has been drawn up and is constantly updated and religiously followed to ensure adequate transport for MSW collection and transportation at all times. The municipality also boasts a well-planned and well-organised vehicle allocation system for the various transfer stations, MSW generation sources and final disposal sites. Allocation of vehicles of different sizes and capacities is done considering the volumes of waste and location of different facilities for the temporary storage of waste as well as final disposal.

Innovations in Collection of Municipal Solid Waste

The municipality has managed to bring together all essential stakeholders to participate in the collection and proper disposal of waste at appropriate places as it awaits transportation to its final destination. This may have been accomplished by borrowing from the collaborative planning theoretical framework presented in the earlier sections of this chapter. Communities and individuals have of late been participating in the management of MSW by sorting materials for recycling waste. Such efforts need to be supported through the building of strong partnerships among all concerned stakeholders to help improve the situation of MSWM, as has been observed elsewhere.⁵¹

Outcomes of the Innovations in MSW Management in eThekweni Municipality

The project has successfully achieved socio-economic and environmental objectives that foster the sustainability of cities, particularly in the developing world. The Marianhill and Bisasar landfill sites are jointly generating a total of 7,5 MW of electricity, which provides power to about 3 500 residents of the municipality, generating a revenue of R48 million through the sale of certified carbon credits and the sale of electricity to the municipality. The projects are also estimated to generate a total of R400 million in revenue during their life.

Table 11.3: Summary of Innovation Outcomes and Key Findings

Outcome	Description of key findings
Social	Improved standard of living and health; educational support through bursaries given to students; community cohesion through engagement and participation in recycling activities.
Economic	Electricity-generation and supply to residents; monetary rewards from the sale of electricity and carbon credits; and employment creation as skilled, semi-skilled and unskilled personnel work on projects.

Environmental	Carbon-emission reductions; conservation of the environment through the plant rescue unit and reclamation of landfilled areas; water recycling that saves water; and reduction of land and underground water.
Infrastructural	Well-engineered and well-designed landfill sites; well-maintained fleet of adequate and reliable vehicles for transporting MSW.
Institutional	Waste-management and awareness-raising policies and community organisations such as the Keep EtheKwini Beautiful (KEB) that is seized with conscientisation and sensitisation of all the residents about maintaining a clean environment.

(Source: Developed by Authors from field studies, 2013)

The innovations at the landfill site have resulted in the realisation of about 218 000 carbon emissions reductions (CERs) every year since its inception, and the project has generated in excess of 600 000 carbon credits, reducing the burning of coal by 800 000 tonnes every year.

Figure 11.4: Cleanliness: Benefits of Innovations in Municipal Solid Waste Management (MSWM) in eThekweni Municipality



(Source: Authors, 2013)

Innovations in the management of MSW within the municipality have necessitated the development of participatory networks in fighting the scourge of unattended and untreated waste, as evidenced by the establishment of the KEB campaign. KEB is a not-for-profit organisation, created through the collaboration of participants from the private, public and community sectors. It aims to work toward making the city clean at all times, through public conscientisation and sensitisation programmes and projects dealing with the benefits of safe collection, transportation, disposal and treatment of waste.

Challenges with Innovations in MSWM

The MSW phenomenon is a consequence of lifestyles in urban centres, where volumes of waste rise directly with the increase in population and standards of living. Municipalities therefore face serious challenges in the collection, transportation, disposal and treatment of waste. Municipal authorities have, for a long time, single-handedly administered and carried out MSW collection, transportation, treatment and disposal in such a way that other stakeholders have always considered it to be the duty and responsibility of government. Generally there has always been the belief that someone working for the municipality, who is employed to maintain the city clean, will collect and dispose of waste properly and without involving the public, thus creating various attitudes and misperceptions about the management of MSW.³²

This sentiment has also been observed by other scholars, who posit that ordinary people's attitudes and perceptions about waste management (WM) have only recently started to change.³³ Besides, MSW has generally been regarded as worthless, and hence it is a waste of time for residents to engage in the sorting and proper disposal of it. This results in indiscriminate dumping of waste, sometimes at uncontrolled dump-sites, and, in worse scenarios, on river banks, street corners, passageways and at the back of buildings.³⁴ Cities without adequate means of waste collection, transportation and treatment suffer continuously from the indiscriminate dumping of waste, and this is worsened by negative attitudes about safe and secure disposal.³⁵

A number of factors, such as lack of access to adequate recycling and waste-disposal facilities; the inconvenience associated with collecting, sorting and separating waste; the gaps and discrepancies between intentions and actions to participate in proper handling and disposal of waste; lack of government policies, incentives and enforcement measures; and the general mistrust of local government authorities by residents in most developed nations such as Canada, Ireland, the United States America, Japan and Australia perpetuates the negative attitude toward participation in waste management.³⁶ Reviewing the barriers to kerbside recycling of waste by households in the United Kingdom, other scholars discovered a wide range of inhibiting behaviours to the proper and correct disposal of waste. These can be summarised as behaviours related to individuals and households; those related to information and levels of knowledge; local situations of residents; and their general attitudes and levels of motivation.³⁷ Even if MSW is properly disposed of after collection and transportation, there are other challenges in most developing countries. Of greatest concern is both the lack and high cost of modern technology that efficiently and effectively converts waste to energy; particularly the equipment used to suck gas from landfills and the engines used to cool and convert the gas to electricity.³⁸ The few projects already implemented on the African continent, for example, suffer critical

shortages of experienced and well-trained personnel.³⁹ Appropriate policies that support investment in renewable energy production are also lacking in most African countries. Where they exist, there are serious inconsistencies in their application. In the case of eThekweni Municipality, the appropriate technologies, particularly the engines used to convert the gas to electricity, have been very expensive, forcing the municipality to borrow money from international sources. Even maintaining the engines has been a mammoth task for the municipality. The other challenge has been the relative lack of technical know-how, particularly when it came to determining the amount of gas that could be sucked from the landfill sites beforehand. However, in most cases the implementation of the project has been trial-and-error, inevitably leading to wastage of resources.

Conclusions and Recommendations

Although cities face serious challenges, they still remain centres of prosperity, and places where human beings find satisfaction of basic needs as well as convenient access to essential public goods. Ambitions, aspirations and other material and immaterial aspects of life are realised in urban centres. Regardless of their location and their state, they provide some form of contentment and happiness, as well as individual and collective development. Therefore they will continue to attract millions of migrants from rural areas, particularly in developing countries. Efforts should be made to ameliorate the challenges currently being experienced, such as the indiscriminate disposal of MSW, to improve well-being and prosperity and expand on the prospects. This can only be achieved through innovations in approaches and adopting flexible initiatives. There is therefore a need to strengthen the capacity of relevant institutions through improving human, technical and financial resources, and ineffective institutional arrangements. This involves observing rules and regulations, formulating relevant policies and implementing them according to their letter and spirit. There have also been initiatives to promote the participation of local as well as international players in the management of MSW.

In conclusion, improving the currently dire MSW situation in most cities of the developing world calls for innovations in approaches. Such innovation should focus across the spectrum of activities associated with MSWM, from collection to transportation, disposal and treatment. If the immediate and long-term needs of Africans, for example, are to be met, such as the energy demands of the continent's ever-increasing populations, there is therefore a need to change people's behaviour and attitudes so that waste will be regarded and treated as a valuable resource. This can only be possible through awareness-raising and the sensitisation of the general population to its usefulness. Innovations in MSWM also help to ensure the progressive reduction

of GHGs, such as methane and carbon dioxide, which directly cause global warming and climate change. In this regard, the pursuit of sustainable and clean cities or societies calls, not only for a shift in attitudes and views about waste, but also a better and clearer understanding of modern methods of waste management. There is therefore a need for WTE technological uptake and training of personnel to improve the skill-set on the continent. Lessons from practices taking place in a few of the more progressive African countries, such as South Africa and some other countries mentioned in this article, should provide sufficient motivation for the programmes and endeavours being established in other urban centres of the continent. Besides realising the direct benefits of increasing and securing energy sources, scaling up the green revolution on the African continent will also help African countries achieve sustainable socio-economic and environmental development.

Notes and References

- 1 Simelane, T. & Mohee, R., 2012. *Future directions of municipal solid waste management in Africa* (Policy brief no. 81). Pretoria: Africa Institute of South Africa.
- 2 Mutanga, S.S., Pophiwa, N. & Simelane, T., 2013. Cities as green economy drivers: Making a case for green cities in South Africa. In S.S. Mutanga, T. Simelane & N. Pophiwa (eds.), *Africa in a changing global environment: Perspectives of climate change adaptation and mitigation strategies in Africa*. Pretoria: Africa Institute of South Africa.
- 3 Mazhindu, E., Gumbo, T. & Gondo, T., 2012. Waste Management Threats to Human Health and Urban Aquatic Habitats – A case Study of Addis Ababa, Ethiopia. In L.F.M. Rebellon (Ed.), *Waste Management: An Integrated Vision*. Kampala: INTECH. Available at: <http://www.intechopen.com/books/waste-management-an-integrated-vision> [Accessed 4 June 2013].
- 4 Okot-Okumu, J., 2012. Solid Waste Management in African cities – East Africa. In Waste Management – An integrated vision. In L.F.M. Rebellon (ed.), *Waste Management: An Integrated Vision*. Kampala: INTECH. Available at: <http://www.intechopen.com/books/waste-management-an-integrated-vision> [Accessed 6 June 2013].
- 5 Fobil, J.N., Carboo, D. & Armar, N.A., 2005. Evaluation of municipal solid WASTES (MSW) for utilisation in energy production in developing countries. *International Journal of Environmental Technology and Management*, 5(1), pp.76–86.
- 6 Simelane, T. & Mohee, R., 2012
- 7 Strachan, L.J., Wright, M., Pass, J., Couth, B. & Pearson, G., 2008. *Landfill Gas Generation: Theory and Practice*. Conference proceedings at Waste and Resources Management – A shared responsibility. 16–17 September 2008. Warwickshire.
- 8 Gumbo, T., 2013. *Towards a Green Energy Revolution in Africa: Reflections on Waste to Energy Projects* (Policy brief no. 101). Pretoria: Africa Institute of South Africa.
- 9 Rossman, G.B. & Rallis, S.F., 1998. *Learning in the field: An introduction to qualitative research*. California: Sage.

- 10 Leedy, P.D. & Ormrod, J.E., 2010. *Practical research: Planning and design* (9ed.). New Jersey: Pearson Education.
- 11 Babbie, E. & Mouton, J., 2001. *The practice of social research*. Cape Town: Oxford University Press.
- 12 Cohen, L., Manion, L. & Morrison, K., 2011. *Research methods in education*. London: Routledge.
- 13 Schaeffer, N.C., Dykema, J. & Maynard, D.W., 2010. Interviewers and interviewing. In P.V. Marsden & J.D. Wright (eds.), *Handbook of survey research* (2ed.). Bingley: Emerald Group Publishing.
- 14 Babbie, E. & Mouton, J., 2001.
- 15 Fobil, J.N., Carboo, D. & Armar, N.A., 2005.
- 16 Jesson, J. & Stone, I., 2009. *A Review of Barriers to Kerbside Recycling Household Waste in the UK*. Birmingham: Aston Business School, Aston University.
- 17 World Bank/SDC, 2012. *Collaborative programme on municipal solid waste management in low income countries* (Working paper no. 9). Nairobi: World Bank.
- 18 Bartelings, H. & Sterner, T., 1999. Household Waste Management in a Swedish Municipality: Determinants of Waste Disposal. *Recycling and Composting in Economics*, 13(4) pp.473–91.
- 19 Healey, P., 2003. Planning Theory: Collaborative planning in Perspective. *Planning Theory*, 2(2), pp.101–23.
- 20 Innes, J.I. & Booher, D.E., 1999. Consensus Building as Role Playing and Bricolage: Toward a Theory of Collaborative Planning. *Journal of the American Planning Association*, 65(1), pp.9–26.
- 21 Kumar, A. & Paddison, R., 2010. Trust and Collaborative Planning: The Case of the Scottish Planning System. *International Planning Studies*, 5(2), pp.205–23.
- 22 Flyvbjerg, B., 2003. Rationality and Power. In S. Campbell & S.S. Fainstein (eds.), *Readings in Planning Theory*. Massachusetts: Blackwell.
- 23 Windischer, A., Grote, G., Mathier, F., Martins, S.M. & Glardon, R., 2009. Characteristics and organizational constraints of collaborative planning. *Cognition, Technology & Work*, 11, pp.87–101.
- 24 Danese, P., 2011. Towards a contingency theory of collaborative planning initiatives in supply networks. *International Journal of Production Research*, 49(4), pp.1081–103.
- 25 O'Connell, E.J., 2011. Increasing Public Participation in Municipal Solid Waste Reduction. *The Geographical Bulletin*, 52, pp.105–18.
- 26 Harris, N., 2002. Collaborative planning: From Theoretical Foundations to Practice forms. In P. Allmendinger & M. Tewdwrjones (eds.), *Planning Futures: New Directions for Planning Theory*. London: Routledge.
- 27 Chen, X., Haight, M.E., Geng, Y. & Fujita, T., 2010. Managing Municipal Solid Waste from a System Perspective: A Comparative Study of Dalian, China and Waterloo, Canada. *Sustainable Development*, 18, pp.282–94.
- 28 OECD, 2013. *OECD Economic Surveys: South Africa 2013*. Paris: OECD Publishing. Available at: http://dx.doi.org/10.1787/eco_surveys-zaf-2013-en [Accessed 14 June 2013].
- 29 Statistics South Africa (SSA), 2011. *Mid-year population estimates 2011* (Statistical release P0302). Pretoria: SSA.

- 30 Strachan, L.J. & Pass, J., n.d. *Credits where they are Due: Clean Development Mechanism (CDM) Energy from Waste. An Overview of Africa's First Landfill Gas to Energy CDM Projects*. Durban: eThekweni Municipality.
- 31 O'Connell, E.J., 2011.
- 32 Tucker, P. & Speirs, D., 2010. Attitudes and Behavioural Change in Household Waste Management Behaviours. *Journal of Environmental Planning and Management*, 46(2), pp.289–307.
- 33 Zurbrügg, C., 2002. *Urban Solid Waste Management in Low-Income Countries of Asia: How to cope with the garbage crisis*. Paper presented for the Scientific Committee on Problems of the Environment (SCOPE) at the Urban Solid Waste Management Review Session. Durban.
- 34 Mazhindu, E., Gumbo, T. & Gondo, T., 2012.
- 35 Johari, A., Ahmed, S.I., Hashim H., Alkali, H. & Ramli, M., 2012. Economic and environmental benefits of landfill gas from municipal solid waste in Malaysia. *Renewable and Sustainable Energy Reviews*, 16, pp.2907–12.
- 36 O'Connell, E.J., 2011.
- 37 Jesson, J. & Stone, I., 2009. *A review of barriers to kerbside recycling household waste in the UK*. Birmingham: Aston Business School, Aston University.
- 38 Simalenga, T., 2011. Human capital requirements for sustainable renewable energy production. In Simelane, T. & Abdel-Rahman, M., (eds.), *Energy transition in Africa*. Pretoria: Africa Institute of South Africa.
- 39 El-Khattam, W., Hussein, S. & Abdel-Rahman, M., 2011. State of energy infrastructure in Africa: How much investment is needed to migrate to renewable energy? In Simelane, T. & Abdel-Rahman, M., (eds.), *Energy transition in Africa*. Pretoria: Africa Institute of South Africa.

CHAPTER 12

Localised Approach to Solid Waste Management: System Dynamics, Life-cycle Assessment, Institutional and Legislative Frameworks

Geeta Devi Somaroo and Oomesh Gukhool

Integrated Approach to Solid Waste Management

Integrated solid waste management (ISWM) is a comprehensive waste-prevention, recycling, composting and disposal programme.¹ It can be defined as the selection and application of suitable techniques, technologies and management programmes to achieve specific waste management (WM) objectives and goals.² A hierarchy in WM can be used to rank actions to implement programmes within the community.³ The ISWM hierarchy, which was adopted by the United States Environmental Protection Agency (US EPA), is made up of the following elements, in order of priority: source reduction; recycling; waste transformation and disposal. As a concept or principle, the hierarchy makes sense in a way that is difficult to oppose, as it echoes approaches that are widespread in human health and medicine, i.e. the adage that prevention is better than cure. Most would agree that it is more effective to avoid problems from the outset, than to invest in reactive solutions once the problem has been presented. The parallels in human health and environmental protection are similar, and are supported by considerable scientific evidence and knowledge.⁴

Waste streams, collection, treatment and disposal into a practical WM system are combined in an ISWM system, which aims at providing environmental sustainability, economic affordability and social acceptance for any specific region.⁵ An effective ISWM system takes into consideration how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment.⁶ This objective is achieved using a combination of a range of treatment options, including waste reduction, re-use, recycling, composting, bio-gasification, thermal treatment and landfilling.⁷ Another approach exists, similar to the hierarchical system, known as the interactive 'ISWM strategy'. It is a holistic approach, which takes all of the available options into consideration and demonstrates that each of these options plays an important role in an integrated WM system. However, the system itself does not suggest to what extent each of the options needs to be applied. The percentage of

waste treated by each of these options will depend on the local situation. Each option should be assessed using the most recent data available, but the overriding objective is to optimise the whole system, rather than its parts, to make it environmentally and economically suitable and socially acceptable.⁸ Marshall and Farahbakhsh state that the progress of SWM has been driven by five principal factors over the years, namely: public health; the environment; resource scarcity and the value of waste; climate change; and public awareness and participation.⁹ The selection of a better WM scenario requires consideration of many aspects, such as environmental, economic and social ones.¹⁰ The Life-cycle assessment integrated waste management (LCA-IWM) assessment tool is a decision-support tool for WM planning, which allows modelling of WM scenarios at municipal level. The targeted end-user is the municipal officer responsible for WM planning, who, with the assistance of this tool, has better insight into the potential impacts of his or her decisions.¹¹

System Dynamics Approach

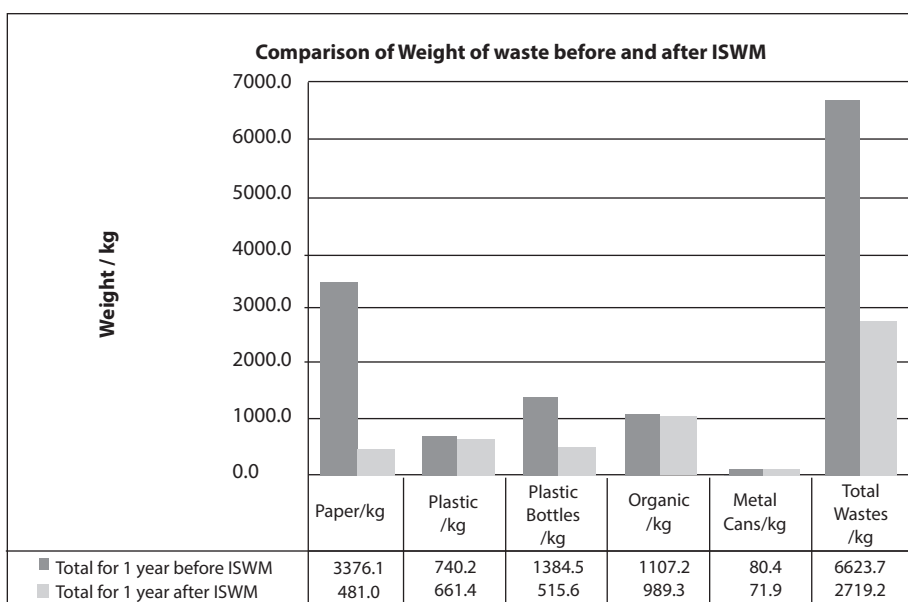
Over the years, SWM has been a topic that has engaged the attention of researchers in operational research (OR) and systems modelling.¹² Simonetto and Löbner added that the use of quantitative techniques in SWM appears a viable alternative to the treatment of the complexity inherent in the process.¹³ Through the use of these tools, it is possible to represent a real-world situation, study its behaviour and make decisions based on the conclusions extracted.¹⁴ Systems analysis is a discipline that harmonises ISWM strategies by providing inter-disciplinary support for decision-making in this area.¹⁵ The analytical framework of WM is provided by systems-engineering models and system-assessment tools, in order to handle particular types of problem areas.¹⁶ Systems-engineering models are a set of related components or sub-systems, which interact with each other and include cost-benefit analysis, forecasting models, simulation models, optimisation models and integrated modelling systems.¹⁷ Factors considered by system-assessment tools include: management information systems; decision-support/expert systems; scenario development; material flow analysis; life-cycle assessment or life-cycle inventory; risk assessment; environmental impact assessment (EIA); strategic environmental assessment; socio-economic assessment; and sustainable assessment areas.¹⁸ System dynamics is a modelling approach harnessed to establish and study the behaviours of complex mechanisms. This modelling technique is appropriate to model the complexities of SWM. However, its application to this type of management has been fairly limited, due to the high level of dependency of parameters. Dirk and Wout have successfully applied system dynamics to analyse household WM policies;¹⁹ their model is founded on the core WM concept of the 3Rs – reduce, re-use and recycle.

Poulsen and Hansen used historical data on organic waste and waste-water treatment during the period between 1970 and 2020 in order to assess the impact of treatment on energy and greenhouse gas (GHG) balances.²⁰ For this study, the authors included the following waste fractions: sewage sludge; food waste; yard waste and other organic waste (paper, plastic, etc.). Waste-water treatment has changed from the direct discharge of untreated waste water to full organic matter and nutrient (N,P) removal, combined with anaerobic digestion of the sludge for bio-gas production, together with power and heat generation.²¹ Additionally, these changes in treatment technology resulted in the waste and waste-water treatment systems progressing from being nett consumers of energy and nett emitters of GHG, to becoming nett producers of energy and nett savers of GHG emissions (due to the substitution of fossil fuels elsewhere). This came about as a result of the diversion of organic waste away from landfilling toward waste-water sludge treatment by anaerobic digestion, for bio-gas production and the incineration of the remaining waste for additional energy production. Poulsen and Hansen predicted that by 2020, both energy and GHG balances could still be significantly improved by reducing the energy consumption for waste-water treatment (primarily for aeration), increasing the efficiency of anaerobic digestion and incineration processes, and source-separation of food waste for anaerobic co-digestion with waste water sludge.²²

At the Faculty of Engineering (FoE) of the University of Mauritius, the management of solid waste follows a pathway consisting of waste collection, storage at the dumping-site or transfer station, and finally transport to the landfill. A better and more effective ISWM strategy is required in order to make the FoE's waste management more environment-conscious. Lam Kam Sang Oy studied how an integrated WM strategy could be implemented at this faculty.²³ The aim of the ISWM was to manage and dispose of waste in such a manner that the environment would be less affected. From a survey conducted recently, it was observed that even the students were of the opinion that an effective ISWM was required for the faculty. SWM would consist of four main activities, with regard to which a policy would be essential in ensuring compliance with environmental regulations and to demonstrate commitment by the top management of the university. Secondly, careful and systematic planning was required, during which measurements were taken from the different buildings forming the faculty, to quantify the amount of waste generated. It emerged that a total of 6 623 kg/year of solid waste was generated, and the proportion of the different waste components was: 50 per cent paper, 11 per cent plastic, 21 per cent plastic bottles, 17 per cent organic and one per cent metal cans. The measures required for implementation of the ISWM would be based on the interactive system of ISWM. The main measures proposed were: the initiation of a sensitisation campaign to reduce waste generation; re-use of paper; installation of water fountains

to reduce the number of plastic bottles being thrown away; as well as integration of paper and plastic, bottle recycling. Recycling companies were also contacted, and an enquiry about the procedures involved was conducted. The last step was continuous monitoring of the implemented ISWM, so as to ensure its effectiveness. A forecast for the amount of waste that would be generated after implementation of the ISWM was also undertaken. The results showed a decrease in waste quantities of around 60 per cent. It must also be noted that participation by the students in the implementation of the ISWM would be essential.

Figure 12.1: Amount of waste before and after implementation of ISWM strategy



(Source: Lam Kam Sang Oy Lan, 2013)

The comparison between the amount of waste generated before implementation of the ISWM and the estimated amount after implementation, revealed a decrease of about 58.9 per cent in total waste per year (Figure 12.1). Among the main changes in waste components were: paper experienced a decrease of almost three tons per year; while plastic bottles decreased by approximately 63 per cent.²⁴ Hence, the total amount of waste to be disposed of in the landfill, after implementation of the ISWM, was approximately 2 719 kg (41 per cent), with a decrease of around 3 900 kg. This value was much lower than the percentage of waste landfilled in an ISWM undertaken in Prato, Italy, but was quite similar to another study undertaken in Lahn-Dill-Kreis, Germany, in 1996.²⁵ The recycling percentage for the FoE was found

to be 32 per cent, compared to Hampshire, England (1996/97), where the value for recycling was nine per cent.²⁶

Life-Cycle Assessment

Life-cycle assessment (LCA) is generally considered as the best environmental management tool that can be used to obtain an objective quantification of all the environmental impacts related to different SWM scenarios.²⁷ Also, LCA methodology is very useful in showing paths that could possibly decrease environmental impacts caused by the WM process.²⁸ An LCA study consists of four phases: goal and scope definition, life-cycle inventory analysis, life-cycle impact analysis, and the interpretation of results. The life-cycle inventory analysis involves data collection and calculation via model development, and the use of a variety of literature data to calculate outputs in terms of air, water and solid wastes emissions. The results of the inventory analysis are then classified into impact categories, such as global warming, acidification, eutrophication and photochemical-oxidant formation in the life-cycle impact assessment phase. For instance, environmental burdens CO₂, CH₄, CO and N₂O can be grouped into emissions, which contribute to the global warming impact category, depending on the life-cycle impact assessment method used. The application of LCA methodology is of great importance in SWM, as it helps in optimising different waste-flow fractions, using various treatment methods, in order to minimise environmental impacts.²⁹ However, the disadvantages of LCA are attributed to the complexity of WM systems, in conjunction with the lack of reliable and harmonised data, which limit the applicability of the results.³⁰ When SWM strategies are considered, it would be interesting to see how the inclusion of other energy sources (e.g. from renewable sources instead of lignite-based power plants) would affect the results.³¹

Many studies have used LCA as an environmental tool for comparing different waste-disposal options or management scenarios. A study carried out by Morselli et al.³² compared landfilling with incineration, and the results showed that incineration was a far better disposal route for municipal solid waste (MSW), when compared to landfilling. The score ascribed to landfill disposal of 608 819 tonnes of MSW was found to be 27 700 000 Pt, far higher than the 15 900 000 Pt estimated for the same amount of MSW being incinerated. A similar study was undertaken in Tianjin, China, where the MSW Management system (which consisted of 48,9 per cent MSW being treated by incineration plants and 49,5 per cent being disposed of in landfills without LFG utilisation) was compared with six other WM options, in terms of global warming potential.³³ It was found that 68 per cent of the total GHG was from landfills, while 26 per cent was from waste-to-energy (WTE) plants. The study also showed that a 39 per cent reduction could be achieved if the landfill gas

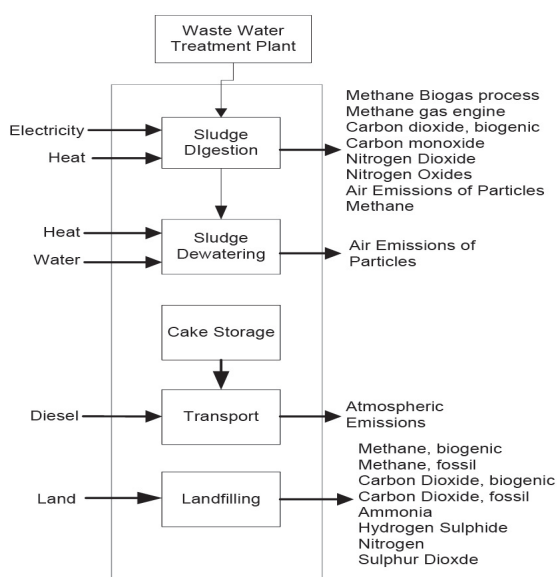
was utilised.³⁴ Incinerating all the waste was also found to be a good option, with a 19 per cent reduction in GHG. The results of an LCA study done by Liansanguan and Gheewala in Thailand to compare incineration with landfilling, showed that landfilling contributed the highest potential to global warming and photochemical ozone formation, due to methane emissions during waste degradation.³⁵

Gunamantha and Sarto conducted an LCA on the following scenarios:³⁶ landfilling without energy recovery, as a representative of existing SWM; landfilling with energy recovery; a combination of incineration and anaerobic digestion; a combination of gasification and anaerobic digestion; direct incineration; and direct gasification. The results of this study demonstrated that LCA could be used as an important tool for assessing and comparing different SWM scenarios for energy in treating solid waste. In addition, Gunamantha and Sarto found that, in view of global warming, eutrophication and photochemical oxidant creation, a combination of direct gasification and landfilling was the most feasible system, with the highest savings of -168 kg CO₂ eq/fu, -0,17 kg PO₄ eq/fu, and -0,16 kg ethylene eq/fu, respectively. In terms of acidification, the combination of gasification, anaerobic digestion and landfilling gave the highest value of saving (-2,8 kg SO₂ eq/fu).³⁷

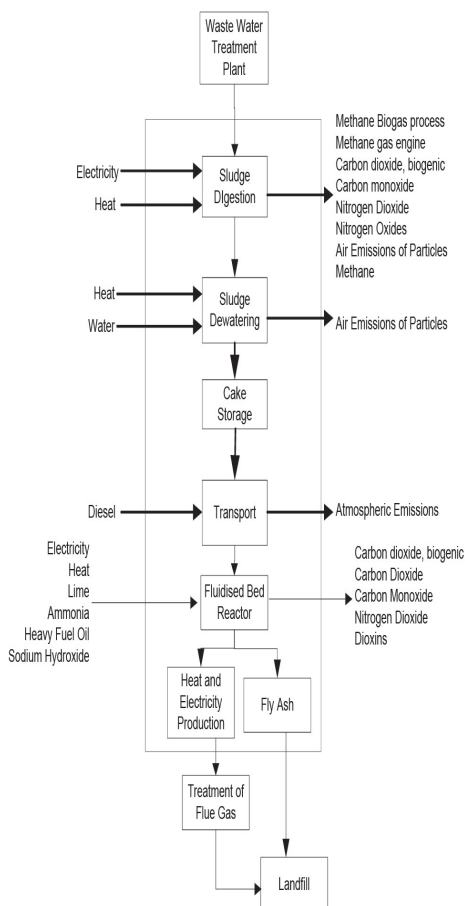
Remy et al.³⁸ analysed the sludge treatment line of large waste-water treatment plants, in terms of cumulative energy demand and the emission of GHG (carbon footprint). Results showed that the existing process is positive in energy balance (-162 MJ/PE [COD]) and carbon footprint (-11,6 kg CO₂ -eq/PE [COD]), by supplying secondary products, such as electricity from bio-gas production or mono-incineration, and substituting fossil fuels in co-incineration. However, disposal routes for stabilised sludge differ considerably in their energy and GHG profiles. In total, LCA proves to be a suitable tool to support future investment decisions, with information of environmental relevance on the impact of wastewater treatment, but also urban water systems in general.³⁹ Murray et al.⁴⁰ evaluated an array of productive end-use options for treated sewage sludge, such as fertiliser, and as an input into construction materials, to determine how the sustainability of traditional manufacturing processes changes, with sludge as a replacement for other raw inputs. The inclusion of the life-cycle of necessary inputs (such as lime) used in sludge treatment impacts significantly on the sustainability profiles of different treatment and end-use schemes.⁴¹ Overall, anaerobic digestion is generally the optimal treatment technology, whereas incineration, particularly if coal-fired, is the most environmentally and economically costly.⁴² The results are intended to help inform and guide decisions about sludge-handling for existing waste water treatment plant (WWTP), as well as those still in the planning phase in cities around the world.⁴³

Seewoodoyal assessed the environmental performance of different treatment alternatives of digested sewage sludge, so as to identify the most efficient treatment system with the fewest environmental impacts.⁴⁴ Four scenarios were studied for the treatment of digested sewage sludge, namely: Scenario 1: Landfilling of digested sewage sludge (actual scenario) (Figure 12.2); Scenario 2: Incineration of digested sewage sludge (Figure 12.3); Scenario 3: Composting of digested sewage sludge (Figure 12.4); and Scenario 4: Direct land application of digested sewage sludge (Figure 12.5). The scenarios were analysed at damage level, using the IMPACT 2002+ impact assessment method in terms of human health, ecosystem quality, climate change and resources. The results obtained show that the contributions of scenarios 1, 2, 3 and 4 were 99 per cent, 0,0001 per cent, 0,029 per cent and 0,002 per cent, respectively, in terms of human health (Figure 12.6). For the damage category eco-system quality, it was found that: Scenario 1 had a contribution of 99 per cent; followed by Scenario 3 (0,5 per cent) (Figure 12.7). Scenario 1 (Figure 12.8) contributed the most to climate change impact (99 per cent), compared to Scenario 2 (0,001 per cent), Scenario 3 (0,04 per cent) and Scenario 4 (0,003 per cent). For the damage category resources, the contribution of each scenario is as follows: 18 per cent, 63 per cent, 17 per cent and two per cent for scenarios 1, 2, 3 and 4, respectively (Figure 12.9).

Figure 12.2: Scenario 1 (Actual scenario)

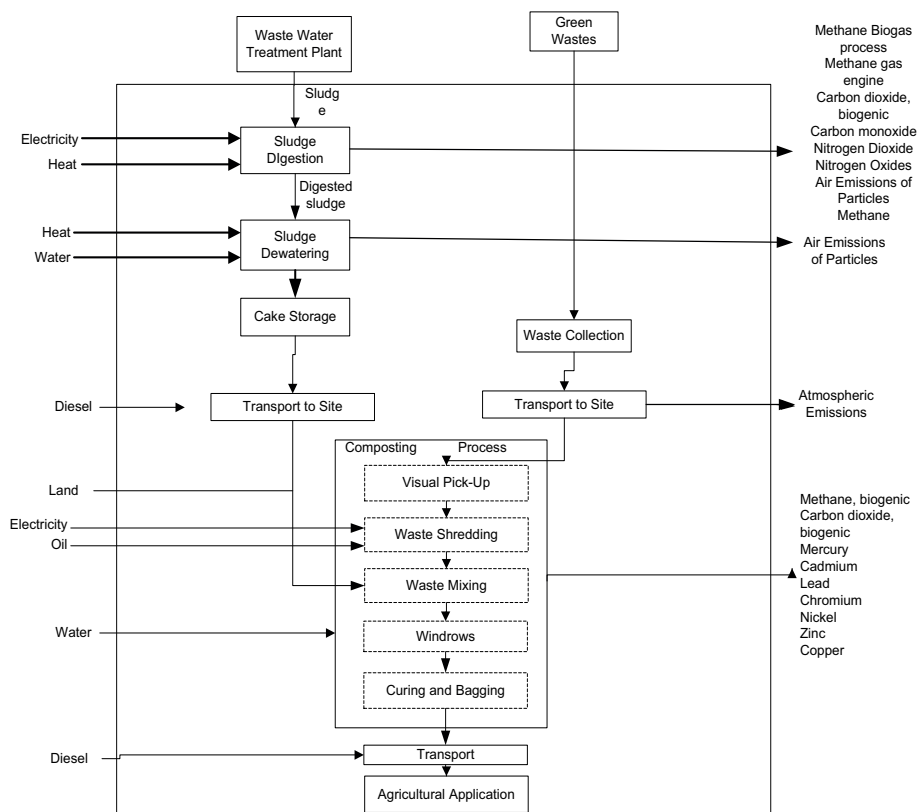


(Source: Seewoodoyal, 2013)

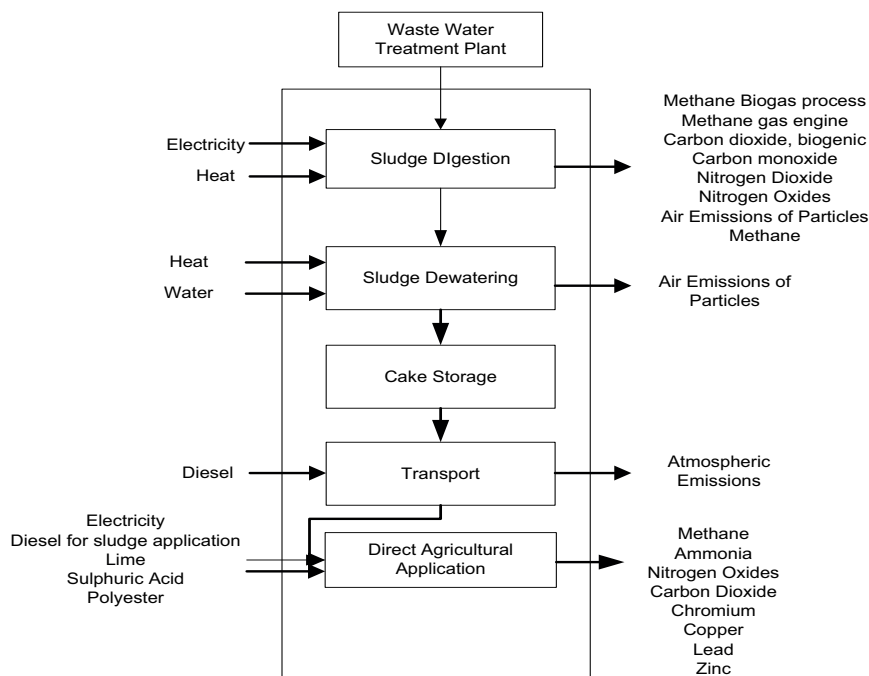
Figure 12.3: Scenario 2 (Incineration of digested sewage sludge)

(Source: Seewoodoyal, 2013)

A study carried out by Suh and Rousseaux on the LCA of alternative waste-water sludge treatment scenarios showed that: a combination of anaerobic digestion and agricultural land application was most environmentally friendly, in terms of less emissions and less consumption of energy; while the most important substances, contributing to human toxicity and ecotoxicity, were heavy metals released from the atmospheric effluent of incineration and from the sludge applied to agricultural fields.⁴⁵ Finally, appropriate tools were required to control the non-point-source pollutants, such as the methane of the dispersed landfill gas and the effluent gases of transport vehicles.

Figure 12.4: Scenario 3 (Composting of digested sewage sludge)

(Source: Seewoodoyal, 2013)

Figure 12.5: Scenario 4 (Direct land application of digested sewage sludge)

(Source: Seewoodoyal, 2013)

Sensitivity Analysis and Parametric Uncertainty

Sensitivity analysis is used to determine how ‘sensitive’ a model is to changes in the value of the parameters of the model and to changes in the structure of the model.⁴⁶ Sensitivity analysis helps to build confidence in the model by studying the uncertainties often associated with parameters in models.⁴⁷ Many parameters in system dynamics models represent quantities that are very difficult, or even impossible to measure with a great deal of accuracy in the real world.⁴⁸ On the other hand, the non-parametric technique of a data-envelopment analysis (DEA) approach allows for the definition of a non-parametric frontier, as a piecewise linear combination of all observations in a sample.⁴⁹ The DEA method presents several advantages, such as: dealing with multiple inputs and outputs; allowing for an intuitive and straightforward interpretation of results (and the decomposition of efficiency); and it is conservative.⁵⁰

Gunamantha and Sarto showed that sensitivity analysis can also be focused on variation in the organic bio-waste compositions by following the pattern variation of 50 per cent, 55 per cent, 60,99 per cent (existing composition), 65 per cent, and 70

per cent; while for other fractions it can be focused by proportionally following the original condition.⁵¹ This simulation indicated that variation in organic bio-waste fractions did not affect the environmental profile in a substantial way.

Rughoonundhun conducted a study on the assessment of the environmental impacts associated with two scenarios, namely: (1) landfilling of MSW (S0); and MSW incineration (S1).⁵² The functional unit consisted of the treatment of 300 000 tonnes of MSW in one year. Processes included within the system boundary were collection and transportation of MSW from its source, incineration and landfilling. The data obtained from the inventory analysis were analysed in terms of the following four damage categories: human health, eco-system quality, climate change and resource depletion, using SimaPro software and Impact 2002+ as the assessment method.⁵³ The damage assessment showed that transportation of the waste contributed significantly to human health in both scenarios (Figure 12.6).⁵³ It was found that landfilling of the waste had an impact of 169 862 DALY on human health, while incineration proved to have an impact of only 72 918 DALY. Transport system 3 contributed the most to human health degradation for the landfilling scenario (160 000 DALY), and involves the transport of 300 000 tonnes of MSW from the point of collection to the transfer station, and subsequently to Mare Chicose landfill.⁵⁴

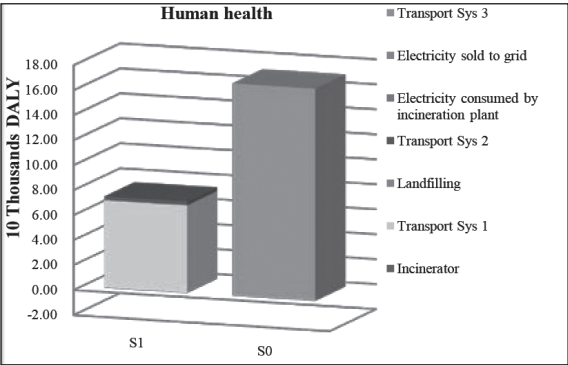
Among the transport systems in incineration scenarios, transport system 1 contributes more to human health degradation than transport system 2.⁵⁵ Transport system 1 involves transporting 300 000 tonnes of MSW to the incineration plant, requiring 20 000 trips, each 66 km long; while transport system 2 involves moving the segregated and un-incinerated waste and ash resulting from the incineration process to the landfill site, which is much less than the 300 000 tonnes of waste collected. The total number of trips required in transport system 2 is, therefore, lower than that in transport system 1.⁵⁶

A sensitivity analysis was carried out for scenarios S0 and S1, but without including the transportation of waste, to determine the environmental impact of landfilling and incineration processes.⁵⁷ S1 involved the incineration of MSW (with the exclusion of metals). It is furthermore observed that the major process in the two scenarios is transport.⁵⁸ Morselli et al.⁵⁹ also showed that the biggest contribution (68 per cent) to human health degradation is from transportation.

The results showed that the impact of the incineration of MSW (S1) on the human health category was much lower when compared to MSW landfilling (S0) (Figure 12.7).⁶⁰ Incineration also involves the production of energy in the form of electricity, thus avoiding the consumption of fossil fuel and emissions to produce an equivalent amount of energy.⁶¹ MSW incineration (S1) produced a gross power output of 93 000 MWh, and consequently avoids an equivalent of 125 DALY.⁶² Cherrubini showed that incinerating 1.46×10^6 tonnes of MSW in Rome resulted in the production of

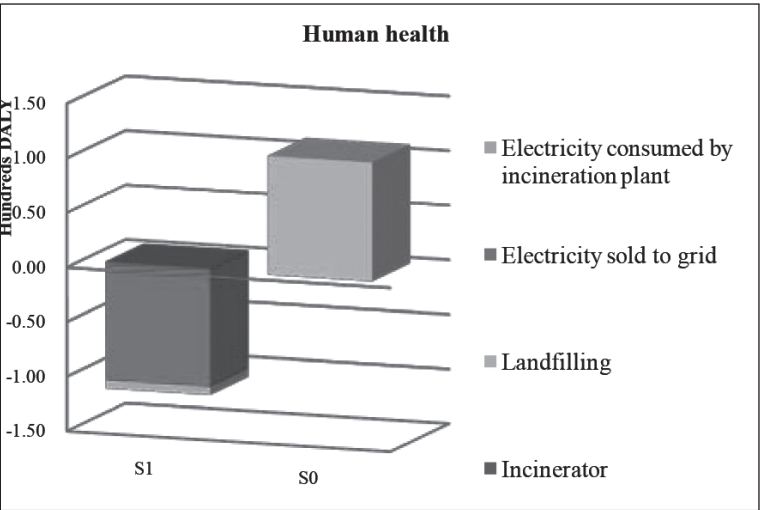
867 000 MWh of electricity;⁶³ while Morselli et al.⁶⁴ showed that the energy produced by incinerating 580 000 tonnes of MSW in Italy, can avoid 789 DALY.

Figure 12.6: Impacts of the scenarios on human health (with transportation)



(Source: Rughoonundhun, 2011)

Figure 12.7: Impacts of the scenarios on human health (without transportation)



(Source: Rughoonundhun, 2011)

Parameter sensitivity analysis is usually performed as a series of tests, in which the modeller sets different parameter values to see how a change in the parameter causes a change in the dynamic behaviour of the stocks.⁶⁵

A study conducted by Somaroo⁶⁶ was done to assess the constituents of air and water emissions, using Monte Carlo analysis for the following scenarios:

- Scenario 1: composting of green waste and degradable plastic-carry bags
- Scenario 2: composting of green waste only.

Since it is difficult to predict what would constitute the emissions to air and water from a composting process, the gases NH_3 , HNO_3 and H_2S were estimated on a daily basis, in order to obtain their emissions to air and water respectively at the end of the composting processes. Microsoft Office Excel 2007 was used to calculate these emissions. It was not possible to model daily emissions of the other gases, due to missing data related to their respective partition coefficients, octanol and water. The other constituents of air emissions from the composting processes consisted principally of CO_2 , CH_4 and N_2O in scenarios 1 and 2, respectively. The purpose of this estimation was to determine the constituents of air and water emissions that contributed the least and the most to environmental impacts/damages for the composting processes only: Scenarios 1 and 2. The different air and water constituents are represented in Table 12.1.

Table 12.1: Different constituents of air and water emissions for Scenarios 1 and 2

Sets	Air Emissions	Water Emissions
1	CO_2 , CH_4 , N_2O , NO_2 and SO_2	
2	CO_2 , CH_4 , N_2O and NH_3	
3	CO_2 , CH_4 , N_2O and SO_2	HNO_3
4	CO_2 , CH_4 , N_2O , NO_2 and H_2S	
5	CO_2 , CH_4 , N_2O , NH_3 and SO_2	
6	CO_2 , CH_4 , N_2O , HNO_3 and SO_2	
7	CO_2 , CH_4 , N_2O , SO_4^- and HNO_3	
8	CO_2 , CH_4 , N_2O and SO_2	
9	CO_2 , CH_4 , N_2O , NH_3 and H_2S	NH_3 and H_2S
10	CO_2 , CH_4 , N_2O , HNO_3 and H_2S	HNO_3 and H_2S

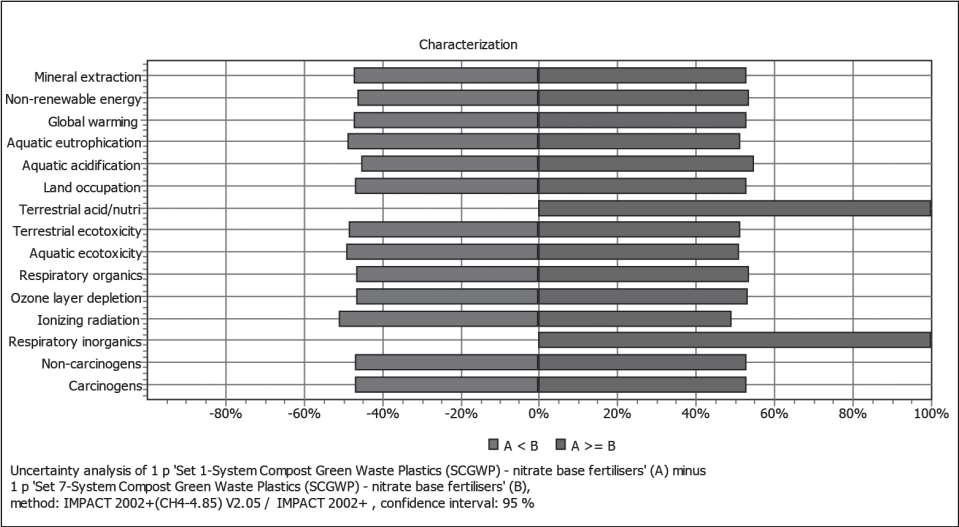
The Monte Carlo simulation was used to conduct the uncertainty analysis for the least and most contributing sets, with one thousand iterations using SimaPro 7.1.8. In a study conducted by Hung and Ma,⁶⁷ 1 000 sets of simulations were produced by means of the Monte Carlo simulation. The uncertainty estimations were given on a unit process level, and the 2,5 per cent and 97,5 per cent values calculated with Monte Carlo simulation were shown for each individual elementary flow. Out of the various individual elementary flows, in the inventory analysis of the different

processes under study, most were obtained from the eco-invent database. The distribution variation of the elementary flows in this study was 'lognormal', and estimated using Pedigree Matrix. Data sources were assessed using the Pedigree Matrix, according to six characteristics: reliability, completeness, temporal correlation, geographic correlation, further technological correlation and sample size.⁶⁸ Each characteristic was divided into five quality levels with a score between 1 and 5.⁶⁹ An uncertainty factor (expressed as a contribution to the square of the geometric standard deviation) was attributed to each of the scores of the six characteristics.

Somaroo found that Set 1 contributed the most to human health and the eco-system, for both Scenarios 1 and 2.⁷⁰ Set 1 consisted of emissions to air of NO₂, SO₂, CO₂, CH₄ and N₂O. Furthermore, the least-contributing set to human health and eco-system damage was found to be Set 7, which included emissions to air of SO₄²⁻, CO₂, N₂O, CH₄ and HNO₃. A Monte Carlo analysis was thus carried out for Sets 1 and 7. Normally, the inventory and impact assessment in LCA is a deterministic model, used for estimating the potential impacts associated with a product.⁷¹ However, one of the limitations of LCA analysis lies in its improper treatment of the uncertainty resulting from the sparse and imprecise nature of available information, and the simplified model assumptions.⁷² Lo et al.⁷³ also point out that the LCA results are often determined from limited data, with unknown reliability. As a rule, the Monte Carlo assessment shows sensitivity to inexactness in input data, whereas Pedigree expresses the quality of the underlying knowledge base of these data.⁷⁴ The results of this Monte Carlo analysis showed the correlations of the two systems under study. However, this analysis cannot state which system was best. Frischknecht et al.⁷⁵ also pointed out that showing minimum and maximum values on the level of LCIA results, without considering the LCIA uncertainties, would be misleading. The model parameters targeted by sensitivity analyses included: MSW transportation distances, sorting efficiency, waste-treatment capacity, impact-weighting methods, recycling programme participation, recovery rates of recyclable materials, waste composition, project time horizons and the cost of MSW transportation and recycling.⁷⁶ Cleary's research can be considered as the first study that conducted a sensitivity analysis on probable air and water emissions from the composting processes.⁷⁷

Figure 12.8 shows the results obtained by subtracting system B (Set 7-SCGWP_Composting site) from system A (Set 1-SCGWP_Composting site) for Scenario 1.⁷⁸ When the impact calculated for system A is greater than that for system B, the result of the iteration is positive (represented by green); while the result is negative when the impact from system B is higher (represented in red). Therefore it was possible to demonstrate if there was a difference between Set 1 and Set 7.⁷⁹

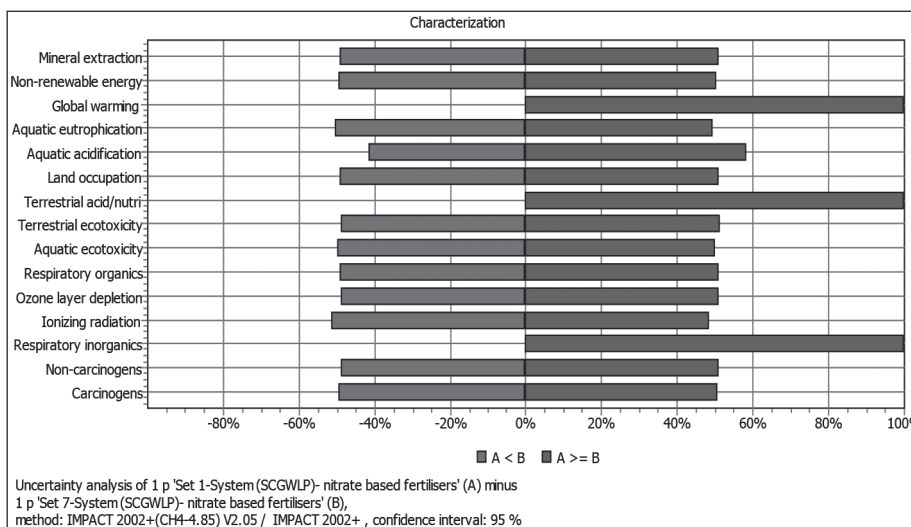
Figure 12.8: Probability occurrence of results obtained from the subtraction of systems (A-B) at impact level of sets 1 and 7 for Scenario 1



(Source: Somaroo, 2011)

There was no difference between Set 1 and Set 7 for terrestrial acidification/nitrification and respiratory inorganics, as the outcomes were 100 per cent positive (Figure 12.8).⁸⁰ It was more than 50 per cent probable that there was no difference in the other impact categories between Sets 1 and 7. Figure 12.9 shows the results obtained by subtracting system B (Set 7-SCGWLP_Composting site) from system A (Set 1-SCGWLP_Composting site) for Scenario 2.⁸¹ Again, when the impact calculated for system A is greater than that for system B, the result of the iteration is positive (represented by green); while the result is negative when the impact from system B is higher (represented in red). It was, therefore, possible to demonstrate if there was a difference between Set 1 and Set 7 for Scenario 2. For the two sets under study, the uncertainty analysis revealed (Figure 12.9) that there was no difference between sets 1 and 7 for global warming, terrestrial acidification/nitrification and respiratory inorganics, as the outcomes were 100 per cent positive.⁸²

Figure 12.9: Probability occurrence of results obtained from the subtraction of systems (B-A) at impact level of sets 1 and 7 for Scenario 2



(Source: Somaroo, 2011)

Institutional and Legislative Frameworks

Local authorities (LAs) of the first level, the municipalities and communities, have a key role to play in supporting changes towards sustainable development. They are responsible for infrastructure development, public procurement and waste management, as well as education, social welfare and physical planning.⁸³ In Mauritius, the Ministry of Local Government and Outer Islands is the body responsible for SWM, including: arrangements for the collection and safe disposal of solid waste; setting up and operating waste disposal sites, such as transfer stations and sanitary landfills; issue of waste carriers' licences; and control of illegal dumping. Under section 156 A of the Local Government Act 1989, it is stated that no person shall:

- (a) deposit, cause or allow waste to be deposited, at a place other than a transfer station or a waste disposal site, or any other site approved for that purpose; or
- (b) throw, drop or otherwise deposit or cause any littering in any street, road, drain, river or other public place, other than in a space or bin specially provided for that purpose.

Every institution has to follow the legislation of its respective country, and universities are no exception. According to some legislation, the waste produced at universities shall be deposited at approved transfer stations or disposal sites.

In Greece, rationalisation of municipal solid waste management (MSWM) requires the establishment of management schemes that ensure safe and systematic collection, economically viable logistics and efficiency/effectiveness of WM services at all levels.⁸⁴ Low-cost, efficient and environmentally effective MSWM is always required, in most cities of the world. However, it is generally acknowledged that developing economies are lagging behind their developed counterparts in this respect.⁸⁵ The significant causes for the lack of waste-minimisation practices in developing economies are: rapid urbanisation; a public relatively uneducated about sustainable consumption practices; non-implementation of the 'polluter pays' principle (PPP); monitoring and enforcement inefficiencies, and the lack of corporate social responsibility and sustainable production.⁸⁶ EU legislative approaches have been adopted by the Hellenic State in its legislative and political framework for MSWM, whereby national needs, demands and priorities regarding the minimisation of MSW production have been addressed.⁸⁷ The focus includes: the establishment of contemporary and integrated programmes and plants, for both recycling and sanitary landfilling; the promotion of source separation programmes; and the establishment of a communication strategy for the promotion of the '4R' concept.⁸⁸

In Portugal, the average landfill tipping fee was about 26 Euros per tonne in 2010 and the diversion of recyclable material from landfills in Portugal saves these costs.⁸⁹ The Sociedade Ponto Verde (SPV) set up the Integrated System for the Management of Packaging Waste in Portugal (the acronym is SIGRE in Portuguese).⁹⁰ SPV is a 'Green Dot' operating entity and is a private, non-profit organisation, founded in 1996, with the objective of promoting the selective collection, sorting, take-back and recycling of, specifically, packaging waste.⁹¹ The various economic agents who participate in the SIGRE, and indeed in all stages of the packaging life-cycle, consist of producers of raw materials and packaging, packers, fillers, distributors, consumers and WM operators.⁹²

The waste-collection process is funded by different forms of local tax, and people are not aware of the actual cost in many countries.⁹³ The charge for waste-collection can be a flat rate, or based on volume or weight. Volume-based billing often means that householders can choose the collection frequency and/or size of the waste bins.⁹⁴ In weight-based billing systems, the householder is charged per kilogram of waste, using collection vehicles equipped to weigh the waste bins at each property.⁹⁵ Economic incentives can cause so-called 'crowding-out' effects, undermining the individual's intrinsic morals and motivation; while external interventions (such as pay-by-weight schemes) may sometimes enhance internalised motivation, by providing positive feedback on the individual's competence and behaviour.⁹⁶

Conclusion

This chapter highlights how SWM can be localised, by integrating it into the operations of the institution. By adopting the life-cycle assessment approach, various studies demonstrated that responsibility for SWM does not rest with the municipality alone. What has been realised, by this practice, is that life-cycle assessment helps to expand the perspective beyond the waste-management system. Of note, however, is that the applicability of LCA for waste-management planning and policy-making is restricted by certain limitations, which are sometimes due to characteristics inherent in LCA methodology, while some are specifically relevant to the context of waste management.⁹⁷

Notes and References

- 1 US EPA (United States Environmental Protection Agency)., 2002, Solid Waste and Emergency Response. *US EPA*. Available at: <http://epa.gov/climatechange/wycd/waste/downloads/overview.pdf> [Accessed on 1 May 2013].
- 2 Tchobanoglous, G., Theisen, H. & Vigil, S.A., 1993. *Integrated solid waste management, engineering principles and management issue*. New York: McGraw-Hill, International Editions.
- 3 Syrian Lebanese Higher Council, 2006. *Integrated Coastal Management Project: Solid Waste Management Guidance Manual*. Latakia: Syrian Lebanese Higher Council. Available at: <http://syrlieb.org/LINKS/SolidWasteManual.pdf> [Accessed 2 May 2013].
- 4 Gertsakis, J. & Lewis, H., 2003. *Sustainability and the waste management hierarchy*: A discussion paper on the waste management hierarchy and its relationship to sustainability. Melbourne: EcoRecycle Victoria. Available at: http://www.ecorecycle.vic.gov.au/resources/documents/TZW__Sustainability_and_the_Waste_Hierarchy_%282003%29.pdf [Accessed 23 April 2013].
- 5 Nordone, A.J., White, P.R., McDougall, F., Parker, G., Garmendia, A. & Franke, M., 2011. Waste Management and Minimization. *Encyclopedia of Life Support Systems*. Available at: <http://www.eolss.net/sample-chapters/c09/E4-13-01-10.pdf> [Accessed 1 May 2013].
- 6 Ibid.
- 7 Lam Kam Sang Oy Lan, S., 2013. *Development of an integrated waste management system at the Faculty of Engineering* (Bachelor thesis). University of Mauritius, Moka.
- 8 Mc Dougall, F., White, P., Franke, M. & Hindle, P. 2013. *Integrated solid waste management: a life-cycle inventory* (2ed). Cornwall: Blackwell Publishing.
- 9 Marshall, R.E. & Farahbakhsh, K., 2013. Systems approaches to integrated solid waste management in developing countries. *Waste Management*, 33(4), pp.988–1003.
- 10 Boer, J.D., Boer E.D. & Jager, J., 2007. LCA-IWM: A decision support tool for sustainability assessment of waste management systems. *Waste Management*, 27, pp.1032–45.
- 11 Ibid.
- 12 Simonetto, E.O. & Löbner, M.L., 2012. Simulation based on system dynamics to evaluate scenarios about the generation and disposal of municipal solid waste. *African Journal of Business Management*, 6(50), pp.11976–85.

- 13 Ibid.
- 14 Ibid.
- 15 Pires, A., Martinho, G. & Chang, N.B., 2011. Solid waste management in European countries: A review of systems analysis techniques. *Journal of Environmental Management*, 92(4), pp.1033–50.
- 16 Ibid.
- 17 Ibid.
- 18 Ibid.
- 19 Dirk, I. & Wout, D., 2010. An analysis of household waste management policy using system dynamics modelling. *Waste Management and Research*, 29(4), pp.351–70.
- 20 Poulsen, T.G. & Hansen, J.A., 2009. Assessing the impacts of changes in treatment technology on energy and greenhouse gas balances for organic waste and wastewater treatment using historical data. *Waste Management and Research*, 27, pp.861–70.
- 21 Ibid.
- 22 Ibid.
- 23 Lam Kam Sang Oy Lan, S., 2013.
- 24 Ibid.
- 25 Ibid.
- 26 Ibid.
- 27 Arena, U., Mastellone, M.L. & Perugini, F., 2003. The environmental performance of alternative solid waste management options: a life-cycle assessment study. *Chemical Engineering Journal*, 96(2003), pp.207–22.
- 28 Koroneos, C.J. & Nanaki, E.A., 2012. Integrated solid waste management and energy production – A life-cycle assessment approach: The case study of the city of Thessalonik. *Journal of Cleaner Production*, 27, pp.141–50.
- 29 Ibid.
- 30 Ibid.
- 31 Ibid.
- 32 Morselli, L., De Robertis, C., Luzi, J., Passarini, F. & Vassura, I., 2008. Environmental impacts of waste incineration in a regional system (Emilia Romagna, Italy) evaluated from a lifecycle perspective. *Journal of Hazardous Materials*, 159(2–3), pp.505–11.
- 33 Zhao, W., Van Der Voet, E., Zhang, Y. & Huppes, G., 2009. Life-cycle assessment of municipal solid waste management with regard to greenhouse gas emissions: Case study of Tianjin, China. *Science of the Total Environment*, 407(5), pp.1517–26.
- 34 Ibid.
- 35 Liansanguan, C. & Gheewala, S.H., 2008. The holistic impact of integrated solid waste management on greenhouse gas emissions in Phuket. *Journal of Cleaner Production*, 16(17), pp.1865–71.
- 36 Gunamantha, M. & Sarto, 2012. Life-cycle assessment of municipal solid waste treatment to energy options: case study of Kartamantul region, Yogyakarta. *Renewable Energy*, 41(1), pp.277–84.
- 37 Ibid.
- 38 Remy, C., Lesjean, B. & Waschnewski, J., 2013. Identifying energy and carbon footprint optimisation potentials of a sludge treatment line with life-cycle assessment. *Water Science & Technology*, 67(1), pp.63–73.
- 39 Ibid.

- 40 Murray, A., Horvath, A. & Nelson, K.L., 2008. Hybrid life-cycle environmental and cost inventory of sewage sludge treatment and end-use scenarios: A case study from China. *Environmental Science and Technology*, 42(9), pp.3163–9.
- 41 Ibid.
- 42 Ibid.
- 43 Ibid.
- 44 Seewoodoyal, A.R., 2013. *Assessing the digested sewage sludge treatment options in terms of environmental impacts in the Mauritian context* (Bachelor thesis). University of Mauritius, Moka.
- 45 Suh, Y.J. & Rousseaux, P., 2002. An LCA of alternative wastewater sludge treatment scenarios. *Resources, Conservation and Recycling*, 35, pp.191–200.
- 46 Breierova, L. & Choudhari, M., 2001. An introduction to sensitivity analysis. *Massachusetts Institute of Technology*. Available at: <http://clexchange.org/ftp/documents/Roadmaps/RM8/D-4526-2.pdf> [Accessed 10 April 2013].
- 47 Ibid.
- 48 Ibid.
- 49 Marques, R.C., Cruz, N.F. & Carvalho, P., 2012. Assessing and exploring (in)efficiency in Portuguese recycling systems using non-parametric methods. *Resources Conservation and Recycling*, 67, pp.34–43.
- 50 Ibid.
- 51 Gunamantha, M. & Sarto, 2012.
- 52 Ibid.
- 53 Ibid.
- 54 Ibid.
- 55 Ibid.
- 56 Ibid.
- 57 Ibid.
- 58 Ibid.
- 59 Morselli, L., De Robertis, C., Luzi, J., Passarini, F. & Vassura, I., 2008.
- 60 Rughoonundhun, M., 2011.
- 61 Ibid.
- 62 Ibid.
- 63 Cherubini, F., Bargigli, S. & Ulgiati, S., 2008. Life-cycle assessment of urban waste management: energy performances and environmental impacts: The case of Rome, Italy. *Journal of Waste Management*, 28(12), pp.2552–64.
- 64 Morselli, L., De Robertis, C., Luzi, J., Passarini, F. & Vassura, I., 2008.
- 65 Morselli, L., De Robertis, C., Luzi, J., Passarini, F. & Vassura, I., 2008.
- 66 Somaroo, G., 2011. *Assessing the degradability of plastic carry-bags in a composting environment and determination of environmental impacts using a life-cycle approach* (PhD thesis). University of Mauritius, Moka.
- 67 Hung, M.L. & Ma, H.W., 2009. Quantifying system uncertainty of life-cycle assessment based on Monte Carlo simulation. *International Journal of Life Cycle Assessment*, 14, pp.19–27.
- 68 Frischknecht, R., Jungbluth, N.M., Althaus, H.J., Doka, G., Heck, T., Hellweg, S., Hischer, R., Nemecek, T., Rebitzer, G., Spielmann, M. & Wernet, G., 2007. Overview and methodology: Ecoinvent report no. 1. *Swiss Centre for Life-cycle Inventories*. Available at: <http://>

- www.ecoinvent.org/fileadmin/documents/en/o1_OverviewAndMethodology.pdf [Accessed 23 January 2010].
- 69 Ibid.
- 70 Somaroo, G., 2011.
- 71 Ibid.
- 72 Ibid.
- 73 Lo, S.C., Ma, H.W. & Lo, S.L., 2005. Quantifying and reducing uncertainty in life-cycle assessment using the Bayesian Monte Carlo Method. *Science of the Total Environment*, 340, pp.23–33.
- 74 Ibid.
- 75 Frischknecht, R., Jungbluth, N.M., Althaus, H.J., Doka, G., Heck, T., Hellweg, S., Hirschier, R., Nemecek, T., Rebitzer, G., Spielmann, M. & Wernet, G., 2007.
- 76 Ibid.
- 77 Cleary, J., 2009. Life-cycle assessments of municipal solid waste management systems: a comparative analysis of selected peer-reviewed literature. *Environment International*, 35, pp.1256–66.
- 78 Somaroo, G., 2011.
- 79 Ibid.
- 80 Ibid.
- 81 Ibid.
- 82 Ibid.
- 83 Zotos, G., Karagiannidis, A., Zampetoglou, S., Malamakis, A., Antonopoulos, I.S., Kontogianni, S. & Tchobanoglous, G., 2009. Developing a holistic strategy for integrates waste management within municipal palnning: Challenges, policies, solutions and perspectives for Hellenic municipalities in the zero-waste, low-cost direction. *Waste Management*, 29(5), pp.1686–92.
- 84 Ibid.
- 85 Ibid.
- 86 Ibid.
- 87 Ibid.
- 88 Ibid.
- 89 Ibid.
- 90 Ibid.
- 91 Ibid.
- 92 Ibid.
- 93 Dahlén, L. & Lagerkvist, A., 2010. Pay as you throw, strengths and weaknesses of weight-based billing in household waste, collection systems in Sweden. *Waste Management*, 30, pp.23–31.
- 94 Ibid.
- 95 Ibid.
- 96 Ibid.
- 97 Ekvall, T., Assefa, G., Björklund, A., Eriksson, O. & Finnveden, G., 2013. What life-cycle assessment does and does not do in assessments of waste management. *Waste Management*, 27(8), pp.989–96.

CHAPTER 13

Conclusion: The Holistic Picture and the Way Forward

Ackmez Mudhoo, Romeela Mohee and Thokozani Simelane

Lessons Learned

Solid waste collection and transportation are important elements for sustainable waste management. With increasing waste-generation, alternative methods for the use of solid waste should be developed. These represent some implications and impacts in terms of future directions of municipal solid waste management (MSWM). There are certain elements related to MSWM that still need to be perfected. This is more evident in Africa. Critical aspects outlined in this volume include a legal framework, policies, human resources, route planning, vehicle types, solid waste types, waste containers, collection types and processes, transfer stations, waste sorting as well as waste handling and optimisation strategies.

Key Solid Waste Management Challenges for Africa

With rapid urbanisation, several African countries are facing waste management (WM) challenges. Chapter 4 outlined principles, key technologies and case studies of MSWM in Africa. Strengths and limitations of several case studies, where anaerobic digestion, composting, incineration, landfilling and recycling are used, have been analysed. The case studies discussed revealed the widespread inefficiencies of municipal authorities. This is the current situation in most African countries, where there is a general lack of sustainable methods for MSWM. In order for African countries to progress to the next level of sustainable solid waste management (SWM) through alternative methods, a consolidated capacity-building exercise is required, with more research and advocacy and, more importantly, political will and popular support.

Recycling Progress

In Chapter 5, attention was drawn to the niche already carved by the Nigerian informal recycling sector. The informal sector is the only form of public recycling currently active in Nigeria. The informal waste workers in Nigeria should, therefore, be integrated into the waste-management strategy of the country, rather than being seen as

a nuisance. This will set a good example of integrating the informal sector into the mainstream of MSWM. The informal sector represents an opportunity and a future strategy to increase efficient methods of MSWM in countries whose economies are still developing. As detailed in Chapter 6, integrating waste scavengers into recycling and material recovery from solid waste have various spinoffs. Separate collection at source is the most commonly suggested option, as it results in waste with better resource value. However, to do this effectively, expertise in WM is needed.

Chapter 7 investigated the challenges and options facing MSWM in Uganda. The chapter indicated that there is a high demand for effective SWM in that country, due to the increasing generation of solid waste by the rising urban population. The waste-collection and waste-disposal systems are still poor in all municipalities because of low funding, technical difficulties and shortcomings, and the socio-cultural status of the country. This poor WM results in the accumulation of waste, which poses aesthetic, environmental and public health issues. This is unfortunately the situation in many African countries, which lack the financial resources and the capacity to make effective use of MSW.

Institutional Reform and Technical Requirements

Social and economic transformation in most sub-Saharan countries has directly influenced the amount of waste produced in these countries. This phenomenon has imposed extreme pressure on authorities to up-scale and provide better SWM services to residents. Chapter 8 reviewed the role of government policies and institutional reforms on technical service delivery, with special focus on SWM in Kampala city, Uganda. This chapter highlighted the fact that the competence of governance in providing sustainable solutions to urbanisation challenges is very important. This, however, needs to be done with great success and efficiency, as can be deduced from the case of Ghana. The metropolitan, municipal and district assemblies in Ghana are responsible for the removal of solid waste in residential neighbourhoods. Yet the issue continues to saddle most local authorities with serious environmental problems. Most of the authorities prioritise getting rid of waste 'out of sight'. There is little focus on the proper treatment and management of waste, and this represents a potential danger to both the environment and to human health. The few authorities who have recognised this problem have sought costly, foreign-based technologies via public-private partnerships with firms mainly from the North, without recourse to local conditions. These new technological developments have been ill-fated, a development which, in the first place, has its roots in the manner in which such interventions are conceived, without the appropriate local knowledge and content.

Research Requirements

General Considerations

Chapters 10 and 11 reviewed the strengths and limitations of current practices in urban MSW management in South Africa. The system is compared to that of other countries, particularly in the developed world. Waste-pickers in urban areas are recognised by local government, and in the initiatives of some municipalities who seek to integrate alternative methods of using MSW for energy. These initiatives have helped in the recycling of urban MSW, and more could be done if they were organised into co-operatives. This suggests that more research is needed into the role of co-operatives in MSW management in Africa.

Chapter 12 presented a concept of life-cycle assessment, so as to assess the flow of materials, energy and costs in national and international MSWM systems, particularly with regard to their economic and environmental impact. The process parameters include the processes for transportation, collection, sorting and treatment. A sensitivity analysis and parametric uncertainty assessment were performed to determine the strengths and weaknesses of WM systems currently in operation. What the chapter indicated is that institutional and legislative frameworks are key to providing a coherent and comprehensive national framework for WM, waste diversion, reduction, resource-recovery and recycling. These are needed in order to curb the direct environmental impact of MSW. A number of these have been mentioned, including climate change, sustainability and innovation, as well as employment opportunities. There is, however, a need to identify elements that need to be prioritised by African countries.

Specific Consideration

Medical Waste

Medical waste is defined as any solid waste generated during the diagnosis, treatment or immunisation of human beings or animals which is related to research, production or testing of biological material from all types of healthcare institutions, including hospitals, clinics, dental or veterinary and medical laboratories.¹ This waste type is generally classified as either hazardous or non-hazardous. The World Health Organisation² estimated that around 85 per cent of medical waste is non-hazardous and 15 per cent is hazardous, with 10 per cent being infectious and five per cent consisting of toxic chemical, pharmaceutical or radioactive waste. For African countries, this traditional estimate is inconsistent, as the percentage of hazardous waste varies from country to country: Nigeria has about 26,5 per cent, sub-Saharan African countries have between two and ten per cent,³ and the urban areas of Tanzania have about 50 per cent.⁴

Medical WM has become a critical issue, as the hazardous medical waste poses a potential threat to both human lives and the environment. Medical waste in African countries has not received sufficient attention. Poor medical WM systems were observed in South Africa, Mozambique, Swaziland, Kenya and Tanzania.⁵ This is because, very often, health issues compete for the very limited resources available. Medical waste must be separated from municipal waste, but in many parts of Africa it tends to be collected along with the rest of the waste stream.⁶

There is also a lack of capacity to properly dispose of medical waste, resulting in illegal dumping practices. It is estimated that about 45 per cent of medical waste is generated in the region of South Africa alone. Abor⁷ revealed that in at least one Southern African hospital there is a lack of necessary rules, regulations and instructions, as well as a lack of education and training on the different aspects of collection and disposal of medical waste. Surveys done in Cameroon, Chad, Côte D'Ivoire, Guinea-Bissau and Uganda between 1997 and 1998 showed a complete absence of safe disposal of used needles. But most of these African countries nowadays use incineration to destroy infected medical wastes. In Ethiopia, 42,5 per cent (17 out of 40) of health institutions used a local type of incinerator to handle used needles and sharp objects.⁸ However, if not carried out properly, incineration of medical waste may result in a variety of health problems, such as disrupting the body's hormonal, immune and reproductive system, or causing cancer.

Mining and Radioactive Waste

The exploitation of mineral resources through mining has been one pillar contributing to the rapid development of the African regions. The insatiable quest of the mining industry for minerals such as gold, platinum, coal and other radioactive materials has led to the evolution of the extractive technologies used. However, these operations inevitably resulted in the production of mining and radioactive waste materials, threatening the ecosystem as well as the health of the local population. The foremost challenge therefore is to reconcile the conflict of interest between the avarice of mining companies to further expand mining operations with the need to find remediation measures to limit environmental damage.

Solid waste generated from mining operations consists mainly of 'tailings', slags, coarse dusts and fine particulates.⁹ A relatively small percentage of this waste is discharged in water streams and in the form of air emissions.¹⁰ The major environmental problem encountered with mining operations is acid mine drainage (AMD), which is in fact an oxidation reaction taking place when the contaminants present in mined tailings or rocks are exposed to water and oxygen, and which results in the production of acids as well as metal dissolution.¹¹ The production of this AMD infiltrates and not only contaminates the soil, but also pollutes groundwater. Recent

case studies have revealed the extent of the ecological devastation caused by the effect of limited treatment options for AMD in South Africa. The uncontrolled release of AMD and other metals-contaminated discharges means that rivers and portions of land surrounding the mining zones are unable to sustain any plant growth or any other activity.¹² Consequently, AMD-contaminated lands are in fact waste lands.

The active and passive methods are currently being used for the treatment of water contaminated by AMD. The active method consists of conventional unit operations, such as flocculation and sedimentation. The passive method, on the other hand, involves the use of roughing filters using charcoal,¹³ wetlands, and the Rhodes bioSURE process. However, due to limitations in the availability of certain resources, passive methods are most commonly used in the African regions, more precisely in South Africa.¹⁴ Interestingly, both the passive and active methods transfer the contaminants from a liquid state to a solid state in the form of sludge or other bio-solids.

As far as the presence of AMD and other soil contaminants such as heavy metals and metalloids is concerned, other treatment alternatives, such as land-liming, are also under consideration. This technique is mostly used as a land rehabilitation measure.¹⁵ This method, however, can only prevent soil contamination to a certain extent. In order to further reduce the waste generated by mining, the Green mining concept has been adopted in Asian countries, and aims at implementing the 3R (reduce, re-use and recycle) strategy.^{16,17}

The treatment of radioactive waste has been a sensitive issue, due to a lack of environmental regulations pertaining to disposal options. In an effort to prevent radioactive contamination of water streams, South Africa considered the use of long-term storage containers, and purification methods such as ion-exchange.¹⁸ However radioactive waste, such as that arising from uranium mining, is now handled differently from other mining waste, due to the reactivity of the material.¹⁹ The failure of chemical and physical methods to destroy the radioactive waste generated led to a change in treatment strategy. The chosen method was to focus on rehabilitation measures and other means of disposal. Encapsulation of mining waste is considered to enclose the radioactive materials, and tends to effectively prevent contamination of any kind.

Electronic Waste Management

In this technologically advanced era, the exponential surge in the manufacture and consumption of electrical and electronic equipment (EEE) has inevitably resulted in the piling up of waste from EEE (WEEE), also known as e-waste. This covers a wide spectrum of WEEE, incorporating obsolete and non-functioning ones, valuable ones and toxic substances: televisions, computers, cell phones, home appliances containing non-precious metals such as iron, steel or copper; precious metals such as gold,

silver and platinum, as well as hazardous substances such as lead-containing glass, mercury and acid batteries.²⁰ WEEE has emerged as a pressing issue of great concern in SWM, not only due to the growing quantities of waste, but also because of the complexities involved. Developed countries have intelligently resorted to preventive measures by adopting conventions, directives, stringent laws and policies for regulating the disposal of e-waste.²¹ Nevertheless, developing countries are lagging some distance behind, owing to the escalating WEEE that is either internally-generated or imported illegally as 'used goods', in an attempt to bridge the so-called 'digital divide'.²² The situation is reaching alarming levels on the African continent, which has become a major destination for obsolete EEE worldwide.²³

While the Basel Convention and Basel Action Network (BAN) represent the foremost global initiatives aimed at tackling WEEE issues, for both the developed and the developing world, they did not deter illegal dumping of toxic WEEE in African countries such as Ghana, Nigeria, South Africa and Kenya.²⁴ The absence or lax enforcement of environmental laws, e-waste legislation and policies, coupled with a lack of technology, skills and unexplored business and financing opportunities in the African countries have further fuelled such unscrupulous practices.²⁵ No integrated frameworks exist for monitoring and managing toxic and hazardous e-waste in African countries, owing to the lack of funding and the slow progress with respect to waste minimisation and sustainable development programmes in households.²⁶ A documentary produced by the BAN revealed insights into the rapidly-surging trade in used and obsolete EEE being dumped by industrialised nations into African ports.

Management of e-waste in African countries includes back-yard or informal recycling, involving intensive manual dismantling of equipment, without appropriate facilities to safeguard the environment or human health. The trouble is precipitated through acid-leaching of printed-circuit boards, chipping and melting of plastic without proper ventilation, burning of cables in the open air for recovery of metals, and disposal of unsalvaged materials in fields, swamplands or on river banks. Open fires are often tended by children, who are paid by dealers for the collection of precious metals, such as copper. The working conditions are socially and environmentally deplorable, as informal collectors, dismantlers, recyclers and, eventually, the general population are exposed to highly-toxic e-waste through inhalation of the vapours it gives off when burnt.

Some of the major challenges Africa is facing in terms of e-waste management are the absence of infrastructure and appropriate collection, recycling of WEEE and legislation. Initiatives undertaken to address the challenge of WEEE in South Africa include the 'Global Knowledge Partnerships in e-Waste Recycling' programme, implemented by the Federal Laboratories for Materials Testing and Research (EMPA) and successfully initiated as early as 2004 in the three South African provinces

of KwaZulu-Natal, Western Cape and Gauteng. Hence there is a dire need for new sustainable, eco-efficient and feasible management options. The implementation of legislation or policies in the form of revised and improved extended producer responsibility, mandating producers, importers and retailers with the cost of collecting, recycling and disposal of WEEE, as is the case in industrialised countries, would also be beneficial. Other alternatives include establishing standards and a certification mechanism for second-hand appliances and recycling, and disposal facilities to ensure safety and the environmentally-sound processing of WEEE. Additionally, regional recycling centres could be set up through cooperation between regional bodies such as the African Union and the New Partnership for African Development (NEPAD). Yet the fate of WEEE remains unpredictable, unless necessary corrective action is taken.

Trans-Boundary Movement of Solid Waste in African Countries

Over the years, the practice of dumping hazardous and radioactive waste from the rich to the poor world has been mainly due to the increasing cost of waste disposal and environmental concerns in industrialised and, developed countries. Due to inappropriate environmental regulations and a weak position in the international political economy, Africa was the most attractive, cheapest and least tedious alternative for the disposal of toxic waste originating from developed countries.

The Basel Convention came into force in 1992, and had as its aim the protection of the African continent by controlling the trans-boundary movement of hazardous waste from Organisation for Economic Co-operation and Development (OECD) countries to non-OECD countries.

Contrary to the Bamako Convention, and covering a less-wide range of hazardous wastes, the Basel Convention and other comparable regimes place no ban, but only regulate the flow of hazardous waste. Through the Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement of Hazardous Waste within Africa, the OAU pressurised OECD and other countries to outlaw the import and trans-boundary movement of hazardous waste into Africa. By early 1991, the Bamako Convention had been signed by twelve African countries. It includes stringent criminal liability and calls for fierce penalties to be imposed on those guilty of importation – and hence dumping – of hazardous and radioactive waste into Africa. Dumping of waste in the ocean, including in internal and territorial waters, as well as the import of hazardous products from manufacturing countries where these have been outlawed, were also banned from entry into Africa. Furthermore, the Bamako Convention is predicated on a preventive and precautionary approach, which mandates states to prohibit any kind of releases into the environment, and hence stimulates clean production methods.

By 2007, a total of 29 independent countries that make up the African Union had signed the Bamako Convention, while a further 23 countries had ratified the treaty, which shows the lack of political will of African countries, which largely influences implementation of such environmental regulations. African leaders and countries should be encouraged to ratify the Convention by providing appropriate funding and support from all levels for its complete implementation.

Political and Institutional Policy Requirements

The implementation of a proper WM strategy depends, first and foremost, on political stability and political willingness.²⁷ A stable government ensures that policies adopted remain in place for longer, and this allows sufficient time for a proper WM strategy to develop. Apart from a stable government, there must be willingness on the part of the government to develop and implement a WM system. Without such eagerness and motivation from the government, it becomes almost impossible to implement a fully-integrated WM approach. With political willingness comes a series of attributes, such as proper infrastructure, much-needed funding and law-enforcement and regulations governing SWM. Besides government, the private sector has a major role to play in a proper WM. Public-private partnerships PPPs help to ensure that everyone is taken on board, and this helps to further develop the WM system with additional ideas and know-how from private partners, such as non-governmental organisations (NGOs), while private companies can contribute to the WM system by means of funding through their corporate social responsibility (CSR) programmes.²⁸

Funding Requirements

Funding is principally needed for the implementation of a WM strategy, without which various attributes, such as human-resource development and capacity-building, proper internal infrastructure and appropriate SWM technologies, cannot be developed and implemented. Funding can be obtained in the form of incentives, or through preventive measures. Incentives involve deposit schemes, tax-refund systems and financial aid programmes, such as subsidies on recycling activities; while preventive measures involve environmental taxes, charges and fees levied on emissions or products.²⁹ Besides, private companies can help fund the WM system through their CSR provisions, as mentioned previously, while NGOs can distribute free plastic bins, for instance to local citizens, for source-segregation of waste.

Human-Resource Development and Capacity-Building

To implement a proper waste-management strategy in Africa, one of the main attributes that needs to be taken into consideration is the awareness, training and education of local authorities and the general population. Local authorities need to be aware of the role they play in SWM, and need to know how to plan for variations in waste generation, as well as how to properly collect, transport and dispose of waste. Public awareness and attitudes to WM can also affect a population's willingness to engage in WM practices.³⁰ As such, the general public needs to be sensitised, through awareness campaigns organised by municipalities and NGOs, about health hazards as well as the re-use opportunities of wastes.

Internal Infrastructure

One of the major problems in WM in Africa is the lack of internal infrastructure and appropriate collection systems required for proper WM. After local authorities have been made aware of their responsibilities and the necessary funds are available, the development of proper internal infrastructure is the next step towards a sustainable WM strategy for a cleaner Africa. At the point of waste-generation, the importance of waste segregation is emphasised and encouraged. For instance, appropriate bins should be given to waste-generators for waste storage and storing. A minimum of two bins can be provided, whereby one bin is dedicated to recyclable materials such as glass, metals and plastics, and the second should be for organic materials, such as food and yard waste. Upon transfer of the waste, proper collection vehicles need to be purchased. Obsolete vehicles, which are not economical and are ineffective, need to be replaced. Proper servicing of collection vehicles should take place on a regular basis.³¹ Besides, appropriate waste-transfer stations should be developed for reception and temporary storage of waste prior to transfer to dedicated waste-treatment centres.

Technological Requirements and Transfer

From previous chapters, waste compositions in African countries are such that organic matter is the main constituent of MSW, while recyclable materials represent the next-highest constituent. As such, MSW from these countries is adapted to biological treatment systems, such as composting and anaerobic digestion, while the recyclable fraction is mostly suited to recycling and waste-to-energy technologies such as incineration, pyrolysis or gasification. However, due to a lack of expertise and know-how regarding WM technologies, training and knowledge on these technologies needs to be imparted to local authorities. This can be achieved through transfer of technologies from developed countries to African countries, whereby local authorities are equipped with the skills required to operate the specific WM technologies.³² It must

be pointed out that these technologies need to be adapted to African economies, and that they cannot necessarily be copied like-for-like from what is practised in developed countries. Besides these treatment technologies, dedicated sanitary landfill sites need to be developed for untreated or hazardous waste disposal in such a way that they comply with environmental regulations and minimise health effects.

Legal and Regulatory Framework

Existing local regulations, such as the 'polluter pays' principle and environmental taxes, must be enforced, while new laws governing the act of illegal dumping and back-yard burning must be introduced, where they do not exist. The policy of 'zero tolerance' must be applied, whereby every illegal act of waste mismanagement is punished through fines. Besides preventive measures, incentive measures can be proposed through appropriate regulations, whereby financial aid programmes, such as subsidies, can be granted to WM technologies such as recycling, composting or anaerobic digestion. Furthermore, the Bamako convention needs to be reinforced, and the trans-boundary transfer of wastes from OECD countries to African countries must be minimised, if not banned altogether.

Notes and References

- 1 Manyele, S.V., 2004. Medical waste management in Tanzania: Current situation and the way forward. *African Journal of Environmental Assessment and Management*, 8, pp.74–99.
- 2 World Health Organisation (WHO)., 2004. *Preparation of national health care waste management plans in sub-Saharan countries: A guidance manual*. Geneva: WHO.
- 3 Lubick, N., 2012. Shifting mountains of electronic waste. *Environmental Health Perspectives*, 120(4), pp.148–9.
- 4 Abor, P.A., 2007. Medical waste management practices in a Southern African Hospital. *Journal of Applied Science and Environmental Management*, 11(3), pp.91–6.
- 5 Kgathi, D.L. & Bolanee, B., 2001. Instruments for Sustainable Solid Waste Management in Botswana. *Waste Management Research*, 19, pp.342–53.
- 6 Ibid.
- 7 Yoseph, W., 2004. *Assessment of the Safety of Injections and Related Medical Practices in Health Institutions at Sidama Zone, SNNPR* (Master's thesis). Addis Ababa: Addis Ababa University,
- 8 Csavina, J., Field, J., Taylor, M.P., Gao, S., Landázuri, A., Betterton, E.A. & Sáez, A.E., 2012. A review on the importance of metals and metalloids in atmospheric dust and aerosol from mining operations. *Science of the Total Environment*, 433, pp.58–73.
- 9 Makgae, M., 2011. Key areas in waste management: A South African perspective. In S. Kumar (ed.), *Integrated waste management* (Volume II). Kampala: INTECH. Available at: <http://www.intechopen.com/books/integrated-waste-management-volume-ii/key-areas-in-waste-management-a-south-african-perspective> [Accessed 10 January 2013].

- 10 Tutu, H., McCarthy, T.S. & Cukrowska, E., 2008. The chemical characteristics of acid mine drainage with particular reference to sources, distribution and remediation: The Witwatersrand Basin, South Africa as a case study. *Applied Geochemistry*, 23, pp.3666–84.
- 11 Durand, J.F., 2012. The impact of gold mining on the Witwatersrand on the rivers and karst system of Gauteng and North West Province, South Africa. *Journal of African Earth Sciences*, 68, pp.24–43.
- 12 Nkwonta, O.I. & Ochieng, G.M., 2010. Total Dissolved Solids Removal in Wastewater Using Roughing Filters. *Chemical Sciences Journal*, CSJ-6.
- 13 Ochieng, G.M., Seanego, E.S. & Nkwonta, O.I., 2010. Impacts of mining on water resources in South Africa: A review. *Scientific Research and Essays*, 5(22), pp.3351–7.
- 14 Öhlander, B., Chatwin, T. & Alakangas, L., 2012. Management of sulfide-bearing waste. A challenge for the mining industry. *Minerals*, 2, pp.1–10.
- 15 Bian, Z., Inyang, H., Daniels, J., Otto, F. & Struthers, S., 2010. Environmental issues from coal mining and their solutions. *Mining Science and Technology*, 20, pp.215–23.
- 16 Soo-kyung, K., Dong-hyo, Y., Rao, S.V., Chul-woo, N., Kang-in, R. & Jeong-soo, S., 2012. A new approach to the recycling of gold mine tailings using red mud and waste limestone as melting fluxes. *Geosystem Engineering*, 15, pp.44–9.
- 17 Badenhorst, J.J. & Meyer, W., 2008. Treatment of historical uranium contaminated radioactive waste at Necsa for disposal. In B.J. Merkel & A. Hasche-Berger (eds.), *Uranium, Mining and Hydrogeology*. Berlin: Springer.
- 18 Lottermoser, B.G., 2010. *Mines Wastes: Characterization, Treatment and Environmental Impacts* (3ed.). Berlin: Springer.
- 19 Wang, F., Huisman, J., Meskers, C.E.M., Schluep, M., Stevels, A. & Hagelüken, C., 2012. The Best-of-2-Worlds philosophy: Developing local dismantling and global infrastructure network for sustainable e-waste treatment in emerging economies. *Waste Management*, 32(11), pp.2134–46.
- 20 Nnorom, I.C. & Osibanjo, O., 2008. Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries. *Resources, Conservation and Recycling*, 52, pp.843–58.
- 21 Frazzoli, C., Orisakwe, O.E., Dragone, R. & Mantovani, A., 2010. Diagnostic health risk assessment of electronic waste on the general population in developing countries' scenarios. *Environmental Impact Assessment Review*, 30, pp.388–99.
- 22 Lubick, N., 2012.
- 23 Prakash, S., Manhart, A., Amoyaw-Osei, Y. & Agyekum, O.O., 2010. *Socio-economic assessment and feasibility study on sustainable e-waste management in Ghana*. Berlin: Öko-Institute.
- 24 Nnorom, I.C. & Osibanjo, O., 2008.
- 25 Ongondo, F.O., Williams, I.D. and Cherrett, T.J., 2011. How are WEEE doing? A global review of the management of electrical and electronic wastes. *Waste Management*. 31 pp.714–730.
- 26 Oliveira, C.R.D., Bernardes, A.M. and Gerbase, A.E., 2012. Collection and recycling of electronic scrap. A worldwide overview and comparison with the Brazilian situation. *Waste Management*. 32. pp.1592–1610.
- 27 Simelane, T. & Mohee, R., 2012. *Future Directions of Municipal Solid Waste Management in Africa* (Policy brief no. 81). Pretoria: African Institute of South Africa.

- 28 Muniafu, M. & Otiato, E., 2010. Solid Waste Management in Nairobi, Kenya. A case for emerging economies. *The Journal of Language, Technology & Entrepreneurship in Africa*, 2, pp.342–50.
- 29 Tchobanoglous, G., Theisen, H. & Vigil, S.A., 1993. *Integrated solid waste management. Engineering principles and management issues*. Singapore: McGraw-Hill.
- 30 Remigios, M.V., 2010. An Overview of the Management Practices at Solid Waste Disposal Sites in African Cities and Towns. *Journal of Sustainable Development in Africa*, 12, pp.233–9.
- 31 Coffey, M. & Coad, A., 2010. *Collection of Municipal Solid Wastes in Developing Countries*. Kenya: United Nations Human Settlements Programme.
- 32 United Nations Economic and Social Council, 2009. *Africa Review Report on Waste Management (Summary)*. Committee on Food Security and Sustainable Development Regional Implementation Meeting. 27–30 October 2009. Addis Ababa.

Future Directions of Municipal Solid Waste Management in Africa

Transformation and rapid population growth in Africa indicates that urbanisation is one of the key determinants of the future of social dynamics and development of the continent. Linked to these changes are increased production levels of Municipal Solid Waste. This book provides recommendations and solutions that derive from current situations, experiences and observations in Africa. This book is a 'must read' for urban planners, environmental engineering students and lecturers, environmental consultants and policy-makers. The book can also be of great help to municipal authorities, as it outlines future directions of Municipal Solid Waste management. These need to be considered by the municipal authorities of most African countries.

About the Editors

Professor Romeela Mohee is the Vice- Chancellor of the University of Mauritius. She holds an Engineering degree in Energy and Environment from La Grande Ecole d'ingénieurs, Institut National des Sciences Appliquées Lyon, France and a PhD from the University of Mauritius (which was awarded in collaboration with the Clemson University in the United States of America under a Fulbright scholarship in 1996). Prof Mohee has 25 years of academic experience as a Professor and Head of Department in the field of Chemical and Environmental Engineering, as well as, Dean of the Faculty of Engineering. She is a fellow of the Royal Society of Chemistry in the United Kingdom and has been invited several times as key speaker at international workshops and conferences. She was highly involved in the Rio +20 Conference preparatory meeting for Africa.

Dr Thokozani Simelane is a programme leader for Science and Technology at the Africa Institute of South Africa, which has been recently incorporated into Human Sciences Research Council. He holds a Master of Science and a Doctor of Philosophy Degrees from the Nelson Mandela Metropolitan University. He has recently submitted for examination a Doctor of Technology Thesis in industrial engineering at the Durban University of Technology. He has previously worked as manager (Environmental Management Department) at the Council for Scientific and Industrial Research, South Africa. He has published in a number of international scientific journals and recently published two co-edited book volumes, i.e. energy transition in Africa and Africa in a global changing environment-perspectives of climate change adaptation and irrigation strategies in Africa. He is a member of the Standing Advisory Committee on Intellectual Property Rights of South Africa. His research interests are on energy, complex system analysis, industrial processes analysis and environmental management. He is the founding member of South Africa's Chapter of System Dynamics Society.

